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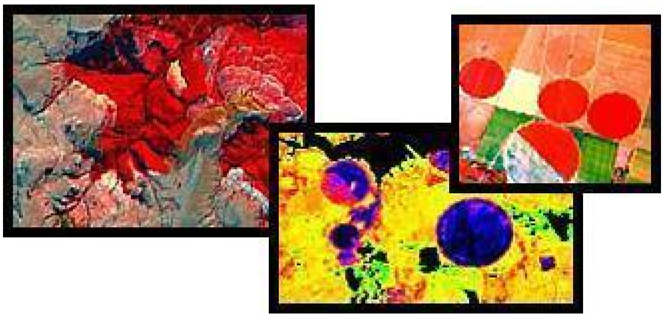
DEPARTMENT OF

WATER AFFAIRS AND FORESTRY

Directorate: National Water Resource Planning

THE MOKOLO RIVER CATCHMENT: VALIDATION OF THE EXISTING LAWFUL USE OF WATER



STUDY REPORT

Final Report

January 2007

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EXECUTIVE SUMMARY

The registration process required that all water uses, regardless of the legal status thereof, had to be registered. The only registration requirement was that it must be an existing use in the qualifying period, whether lawful or not. The qualifying period for groundwater resources is 1 October 1996 to 30 September 1998. For surface water resources the qualifying period is 1 October 1997 to 30 September 1999. The validation of registered water use was therefore critical for the management and control of resources since lack thereof may lead to the establishment of claims to water due to over allocation, an unfair or disproportionate use of water from a resource. The main purposes of the validation process was inter alia to: (i) determine water use for the 1998/99 and current periods, (ii) provide inputs for hydrological modelling and (iii) prepare and compile data sets to be used during the verification of existing lawful water use.

During the registration process some 19 126 ha of irrigation with an associated annual volume of 94.6 million m^3 was registered. The existing lawful water use was determined as 75.4 million m^3/a which includes some 24.2 million m^3/a of the Mokolo River Irrigation Board. The net result of the validation process is an over registration of some 19.2 million m^3/a.

When the existing lawful use from surface water (excluding the Irrigation Board) of 46.2 million m^3/a is compared with the 1998/99 water use of some 52.2 million m^3/a, it is evident that water users were abstracting some 6 million m^3/a more than they were lawfully entitled to. Although the water use decreased between 1998/99 and 2004, the current annual abstraction from surface water resources (47.9 m^3/a) is still some 1.7 million m^3 more that the existing lawful entitlement.

In terms of ground water resources the current annual abstraction of 5.7million m^3/a is some 700 000 m^3 more that the existing lawful entitlement of 5.0 million m^3/a.

An increase in the total storage since 1985 was detected. The total storage in 1985 was some 25.0 million m^3. During 1998 this storage increased to 28.3 million m^3. The latest storage identified in 2004 is some 31.1 m^3. The existing lawful storage is some 28.0 million m^3. While some of the increases in storage were lawful there is currently some 11,7% or 3.1 million m^3 of the current storage development that may be unlawful.

All figures are validated totals (preliminary) as the verification of water use under section 35 of the National Water Act has not commenced. It is therefore necessary to initiate the section 35 process as soon as practically possible.

In order to address the current over-allocation of water downstream of the Mokolo Dam it is proposed that compulsory licensing be implemented as soon as possible (particularly for this area) as this is the only legal mechanism available to rectify this problem.

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ABBREVIATIONS

DTM	Digital terrain model
DWAF	Department of Water Affairs and Forestry
FAO	Food and Agriculture Organisation
GIS	Geographical Information System
GWCA	Government Water Control Area
NWA	National Water Act (1998)
WARMS	Water Authorisation and Resource Management System
WCDM	Water conservation and demand management
PPP	Public participation programme
SAPWAT	SAPWAT is a computer program used for estimating crop irrigation requirements in South Africa and has been released as Water Research Commission Report No. 624/1/99. The program combines crop and climatic databases that enable the water manager to develop realistic estimates that reflect the complex factors that determine average monthly crop water requirements. The program contains extensive default information on crops, climate, soil, irrigation methods and management practices.

1 INTRODUCTION

1.1 BACKGROUND

The Mokolo River catchment is currently in balance based on the available information but there are a number of planned developments that will require additional water resources. The Mokolo Dam situated in the catchment is not performing satisfactorily due to the alleged possible over abstraction by water users. In order to enable realistic modelling the validation and ultimately the verification of the water use is necessary.

The validation of water use includes all the internal measures taken by DWAF to ensure that all the information contained on the registration application is correct and that the information is correctly captured in WARMS. Validation therefore is the checking of all the relevant data and correctness of the submitted registration information using the mechanisms in sec 35 of the NWA. This involves an audit of the WARMS data and using appropriate remote sensing data/ maps/ aerial photography or any other relevant information. The validation process should also highlight unregistered water uses. In terms of this project the objective of validation would be the gathering of water use information in order to be used in the updating of the hydrology. The current yield of the Mokolo Dam could then also be confirmed.

Verification basically refers to the processes described under Section 35 of the NWA and is the next logical step once the validation process is completed. A responsible authority may, in order to verify the lawfulness or extent of an existing water use, by written notice require a person claiming an entitlement to that water use to apply for the verification of that use. A responsible authority may require the applicant to obtain and provide it with other information, in addition to the information contained in the application. The responsible authority may invite written comments from any person who has an interest in the matter and must afford the applicant an opportunity to make representations on any aspect of the application. The verification process is formal and has legal status. The objective of the verification can therefore be seen as the actions that is necessary to accomplish the finalisation of water use entitlements in order to allow for better management of the catchment.

The Mokolo River Catchment encompass an area of some 8 387 km^2 and includes quaternary drainage regions A42A – J. Some 661 farms (***2 516*** subdivisions) are located within the catchment of which 272 farms (1 473 subdivisions) are riparian to public streams.

From the initial WARMS registration information it was evident that water used for irrigation purposes constituted some 87% of the total annual taking of water and that the remaining 13%

was represented by the Industry, Mining and Water Supply Service sectors. It follows that the main focus of the validation and verification project was on water used for irrigation. It is however important to note that the storage within a catchment can have a major impact on modelling. The registration process required that all properties with a total storage capacity in excess of 10 000 m^3 had to be registered. During the Hans Strijdom Dam field survey in 1989 a total of 846 dams were surveyed. Some 600 had a capacity less than 10 000 m^3 that constituted a total volume of 1.27 million cubic metres. The validation of the storing of water therefore focussed on all identifiable storage structures and other impeding structures (specifically weirs) identifiable on the 1998/99 and current satellite imagery. Although the Department may decide that the storage does not have to be registered (if the total storage on a property is less than 10 000m^3), the information is available and would render a more accurate picture and enable better modelling.

The registration process required that all water uses, regardless of the legal status thereof, had to be registered. The only registration requirement was that it must be an existing use in the qualifying period, whether lawful or not. The validation and verification of registered water use was critical for the management and control of resources since lack thereof may lead to the establishment of claims to water due to over allocation, an unfair or disproportionate use of water from a resource. This can lead to the unacceptable situation that such use goes unnoticed or is perpetuated in future. Any unlawful water use must be curtailed as soon as possible especially with the high turnover in ownership as it places new owners (including PDI) in an untenable situation. There are also instances where water users who are entitled to use water were unaware of the registration process and consequently did not register their water use.

A map showing the location of Mokolo River catchment and some basic information is shown in Figure 1. On the map it is evident that the boundary of the Hand Strydom Dam GWA goes beyond the catchment boundaries at certain sections. This is normal and can be attributed to the fact that the delineation of the control area was done on original farm boundaries and not geographic features.

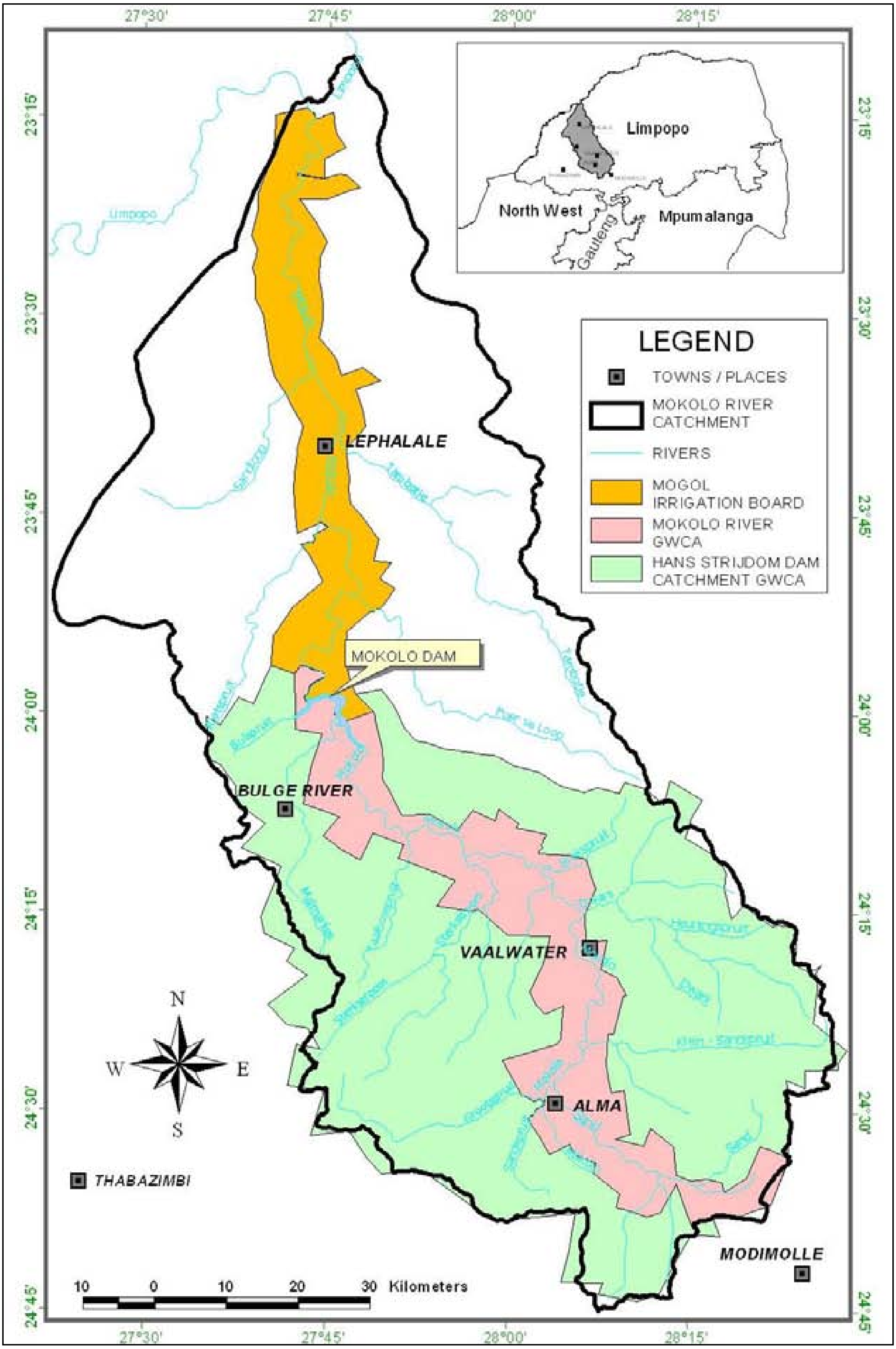


Figure 1: Location map

1.2 PURPOSE OF THIS REPORT

The purpose of this report is to present the following:

- A description of the public consultation process;
- A description of the steps and processes followed during the validation of water use;
- Underlying procedures for the classification of water use;
- A schedule of validated water use;
- Analysis of water use and water demand in the catchment of the Mokolo River.

2 SCOPE OF ASSIGNMENT

In summary, the main scope of service for this assignment was the validation of water use which included the following elements:

- the determination of current (2005) and existing (1998/99) water use;
- determination of the legality of the water use and the quantities of water that the users are legally entitled to according to DWAF's viewpoint;
- classification of the validated water uses as:
  - Correct registration – *water users who have registered their water use entitlements correctly;*
  - Over registration and / or unlawful use – *water users who have registered uses to which they are not entitled to*;
  - Under registration and terminated use – *water users who have omitted to register uses which they are entitled to*; and
  - Failure to register – *water users who have not registered their use at all*.
- provision of water use patterns for use as input for the modelling of water within the Mokolo River Catchment for the date of the promulgation of the Act and for the current situation;
- a final report documenting of all the results, assumptions, inputs and recommendations.

3 PUBLIC PARTICIPATION

During the Inception Phase it became apparent that two other DWAF studies were being conducted in the Mokolo River Catchment, namely;

- The updating of hydrology and systems yield models for the Mokolo River Catchment.
- Water conservation and water demand management (WCDM) potential assessment study for the Mokolo River Catchment

Only the WCDM project had a public participation component and it was thought prudent to align the public consultation components as far as the respective study objectives would allow to ensure an efficient process of stakeholder engagement, negating any potential duplication of activities in the field. The two project managers and the respective Public Participation Team Leaders met and an agreement was reached in terms of the projects aligning the milestones to such a degree that the various teams could present the public with a consolidated programme at the same public meetings.

A revised programme was submitted in draft format to Mr. Hannes Jansen who facilitated a review of the programme with the executive committees of the Alma and Vaalwater Irrigation Forums. The comments from Mr. Jansen and the revised programme were also sent to Ms van Zyl, secretary of the Mokolo WUA for information. The overall comments received were positive and a strong appreciation for the transparent manner in which the process will be run was expressed, importantly, the project team has been assured of a strong support for the project.

An initial identification of water users, stakeholders and affected parties was carried out and the sources of data included organised agriculture, irrigation boards and registered water users on the Departmental WARMS Database. It is important to note that the intention of the Public Participation Programme (PPP) was to support the validation and verification process of the existing lawful water users. The objective of the PPP was therefore to inform the stakeholders in the Mokolo River Catchment of the intended project, the reasons for it and the provision of a port of entry to the teams interacting with the water users during the validation and verification process. The project also included the identification of unregistered water users and the WARMS Database was not able to supply this information. Most of these stakeholders were identified throughout the project as they responded to media announcements of the intended study.

The following section briefly discusses the methodology to achieve the objective of informing a broad base of interested and affected parties. The PPP consisted of three main components that assisted the validation and verification team with its objectives:

- Public Meetings;
- Field visit to the study area;
- Production and dissemination of information products.

3.1 PUBLIC MEETINGS

Public meetings were held at Alma, Vaalwater and Lephalale. These meetings took place at the start of the project and were held between 19 and 21 July 2005. In order to ensure an integrated approach, the technical, as well as a public consultation process were conducted at the same time and representatives of the Validation and WCDM teams and a representative from KUMBA Grootgeluk mine addressed the meetings. The meetings were announced through media releases and advertisements. DWAF Communications Chief Directorate approved the press release on Monday 4th July 2005 and the release was sent to the following media:

- Die Pos
- Mogol Post
- Nu Farmer
- Sunday Times
- Farmers Weekly
- The Rapport Stable (including Landbou Weekblad)

The release was also sent to the following radio stations:

- Radio Sonder Grense
- SAFM
- Thobela FM
- Radio Pretoria

Copies of the official media release, the advertisement and the agenda for the public meetings are included in **Annexure A.** Annexure A and all other annexures are stored electronically on the attached CD.

An integrated set of minutes was sent out to all the stakeholders who participated in the first round of discussions. The rationale for combining the minutes was to enable the stakeholders to get an overall perspective of what the water users across the catchment sentiments were. A copy of the minutes is included in **Annexure B**.

3.2 FIELD VISIT TO THE STUDY AREA

The validation of water use focused on existing (1996-1998 for groundwater and 1997 – 1999 for surface water) and current (2005) water use. During the linking of WARMS registration information to the digitised fields as identified from the satellite imagery, it became apparent that a lot of the registered crops (fields) could not be identified on the satellite images. The normal procedure would have been to flag these registrations and to ask the water users to provide proof that irrigation did indeed take place within the qualifying period (section 35 process).

Although this process was fine, it meant that all the information could not be available to the team responsible for the modelling of the water use. In order to solve this problem and to ensure that the information provided to DWAF was as accurate as possible, a field visit to the area was proposed. The team had discussions with Mr. Beyers Havenga, the Project Manager of the study and the proposed field visit to the area was approved.

A kick-off meeting was held between Mr. Francois Joubert and representatives of the Alma Irrigation forum. The idea of a field visit was well accepted by everyone and they pledged their full co-operation. Possible dates for the field visit were discussed at the meeting and the week of 13 – 17 March was identified as most suitable. Mr. Hannes Jansen of the Alma Irrigation Forum and Mr. Charles Botha of the Vaalwater Irrigation Forum assisted with the advertisement of the field visit by using their ward representatives to herald the visit. An advertisement was also placed in the local newspaper.

The team was available on 13, 14 and 15 March 2006 at the Alma Farmers' Association Hall and on 15, 16 and 17 March at the Vaalwater Farmers' Association Hall.

The response to the field visit was much greater than everyone had anticipated, especially in the Alma area. Water users had the opportunity to sit with the team and carefully examine the satellite images used for the identification of water uses during the 1998/99 period. The current irrigation practices were also confirmed. There were cases where the irrigation could not be identified for a specific date. This is acceptable since the satellite images only provide information for a specific day within a growing season. Where irrigation was unidentifiable, the water users were requested to provide proof that irrigation did take place. A large number of water users provided the additional information while the team was still in the area while information was also forwarded to the team following the field visit.

The general conclusion following the field visit was that water use was over-registered. Some water users, apart form registering their current water use, also registered their planned irrigation. It was explained to the users during the visit that the registration of planned irrigation does not vest a water use entitlement and that any new or planned irrigation (after 1999) is subject to a licence application and the issuing of a licence for such use.

The complexity of the whole validation process was once again confirmed during the field visit and such visits are essential if any meaningful results are to be obtained.

Mr. Sunday Makhuvela of the Limpopo Regional Office represented the Department during the field visit and Mr. Beyers Havenga visited the team on 17 March 2006 at Vaalwater.

During the field visit a total of 248 (or 59%) water use registrations were examined from a total of 421 registrations.

3.3 PRODUCTION AND DISSEMINATION OF INFORMATION PRODUCTS

The objective of the products was to provide various avenues of information dissemination through which the diverse group of interested and affected parties could be informed of the project at different stages.

3.3.1 Background information document

A background information pamphlet was prepared incorporating information pertaining to all three projects being conducted in the Mokolo River Catchment. The newsletter was approved by DWAF on Wednesday 6th July 2005. Newsletters were handed out at the public meetings and sent to everyone registered on the PPP database. A copy of the newsletter is included in **Annexure C**.

3.3.2 Validation results

The preliminary results of the validation exercise were presented to the interested and affected parties during a second round of public meetings. These meetings took place at Alma, Vaalwater and Lephalale between 19 and 21 July 2006. At these meetings the whole validation process was explained and discussed with the water users. In order to ensure that the validation process is transparent, the preliminary validation results for all the properties within a specific area were printed and displayed. A water user therefore had the opportunity to check whether the validated uses for his/her properties were correct and also had the opportunity to provide written comments about the validation results of any other properties. The team was available for the whole day at each venue to handle specific individual questions/problems.

Written comments received from water users were noted and placed on the applicable paper copy validation file. Some 103 comments were received which ranged from additional information provided by water users to queries/comments regarding the extent and/or lawfulness of water use of other water users. A summary of the written feedback received during the second round of public meetings is included in **Annexure D**.

4 VALIDATION PROCESS

The validation of water use focused on existing (1996-1998 for groundwater and 1997 – 1999 for surface water) and current (2005) water use. Part 2 of the *"GUIDE TO DETERMINE THE LAWFULNESS OF EXISTING WATER USES"* and the latest "ADDENDUM TO THE GUIDE" provided an exhaustive breakdown of the processes to be followed when water uses are validated.

Although the processes described in the guide were adhered to, the major processes followed during the validation of water uses are described in detail in the following section.

4.1 PROCESS WARMS DATA AND INCORPORATE INTO CUSTOM DATABASE

Most of the registration information is/was entered into WARMS but is not always readily accessible. Currently, this data cannot easily be queried to give certain answers for a specific scenario *(e.g. What is the total area under maize, using centre pivots, for quaternary catchment C12?)*. Certain vital information such as the extent of a property is necessary during the verification process but the population of this information was not compulsory in the earlier versions of WARMS. This information was obtained and captured on the custom database. Being available in a separate database meant that batch recalculation and updating of irrigation requirements, abstraction volumes, etc. was very quick and easy.

4.2 AUDIT WARMS DATA

The first step in the auditing process was to ensure that the information captured on WARMS and printed out on the Registration Certificate was correct. Apart from checking the correctness of the data, this was also the first step in standardisation. Elements such as language, spelling and standard description of water resources were checked. This is very important since "Mogolrivier" and "Mogol River" are different sources for a software program and may lead to conflicting results when the database is queried in future.

Swapping the coordinates for the latitude and longitude of an abstraction point (taking of water) is very easy. Entered coordinates were therefore checked to ensure that the coordinates for any given registered taking of water are within the boundaries of a property or at least within a reasonable radius from that property. It is very unlikely that a property will receive water for irrigation from a borehole that is 20 kilometres away.

Because Title Deed information is continuously changing, new data were obtained from the Registrar of Title Deeds when the project commenced to check and update registered property owners. This data was ordered in bulk electronic format and parsed programmatically to reduce human error as far as possible.

As with Title Deed information, cadastral data is dynamic and forever changing. Properties consolidated or subdivided since water uses were registered. Cadastral information is also ahead in time of Title Deed information and these discrepancies were sorted out and the changes noted for future reference.

4.3 OBTAIN SURVEY AND OTHER WATER RELATED INFORMATION

Several water right determination studies that included irrigation, which cover the study area or parts thereof, have been conducted in the past (Mogol River GWCA -1982, Hans Strijdom Dam GWCA – 1989). Other data sources that were investigated and incorporated into the historical data pool included the Mogol River Irrigation Board information and previous validation efforts for the Sterkstroom irrigators. The data of the Mogol River GWCA survey conducted in 1982 was only available in hard copy format and this data was manually captured in electronic format. The Hans Strijdom Dam Catchment GWCA survey information was available in electronic format and subsequently merged into the custom validation database.

Each surveyed property was verified against the current registered properties (and the properties registered at the Registrar of Title Deeds) to check if any changes have taken place (subdivisions or consolidations) since the date of proclamation of the specific GWCA. These changes and the impact thereof were cross-referenced and amended to reflect the current situation. The historical information was of utmost importance during the determination of lawful water use.

Although lawful water use could have been determined as was envisaged in sec 9, 9b and 10 of the Water Act (No 54 of 1956) this was not addressed but will need attention when compulsory licensing is undertaken.

4.4 CAPTURE ENTITLEMENTS

During this phase, all gazetted notices, proclamations, entitlements, restrictions, Government Water Control Areas, Irrigation Boards and any other relevant information were captured on the GIS and the supporting database. The total history was captured, showing which proclamations, notices, etc. were withdrawn, replaced or amended by what (if applicable) and on which date.

The history of the different proclamations is shown in table form in **Annexure E-1.** Copies of the relevant proclamations are included in **Annexure E-2.** A map showing the different control areas and the irrigation board area is included in **Annexure K**.

4.5 CALCULATE CROP WATER REQUIREMENTS

In order to calculate the crop irrigation requirements as accurately as possible, certain parameters had to be improved. The SAPWAT program (version 2.6.1 – April 2003) had only one suitable station (Vaalwater) in the study area and this was not sufficient enough to cater for the different climatic regions in the Mokolo River catchment. Areas had to be defined within which the irrigation requirements would be valid. By using the latest rainfall information supplied by the team responsible for the *updating of hydrology and systems yield models* and an agro hydrological data set obtained from the *South African Atlas of Agrohydrology and. –Climatology* (2006), a SAPWAT station was created for each quaternary drainage region.

By using SAPWAT, standard crop irrigation requirements were determined for each quaternary drainage region. **Annexure F** contains the irrigation requirements for each of the identified crop and irrigation system combinations per quaternary drainage region.

4.6 SATELLITE IMAGE PROCESSING

The benchmark for determining the lawfulness of existing water uses is aerial photography taken within the qualifying period (1 October 1996 – 30 September 1999). Any other imagery/ photography taken after 30 September 1999 is for water management and control purposes (to identify possible increases/reductions in irrigated areas and/or storage volumes).

Unfortunately no aerial photography existed for the 1996-1999 period. In the absence of aerial photographs taken close to the date of the promulgation of the National Water Act, Landsat 5 and 7 images were used as the main source to establish existing and current water use. For validation purposes, three dates were identified as important. The first two dates were September 1998 (for groundwater) and September 1999 (for surface water), just before the commencement of the relevant sections of the National Water Act. The third date reflected the current situation and was selected after all the relevant variables were considered.

The Landsat range of satellites passes over the same location every 16 days. The aim was thus to obtain cloudless images as close to the specified dates as possible. The images used during the project are shown in Table 1 .

Table 1: Landsat satellite images

	Landsat 5 Scenes		
	170-077	***171-076***	***171-077***
Acquisition dates	1998-07-31	1998-09-24	1998-09-24
	2001-05-12	2004-08-23	1999-08-26
	2002-09-04		2001-06-04
	2004-08-16		2004-09-08

Due to the size of Landsat images (185 km x 185 km), the ortho-rectification is not precise and some adjustments were necessary. This was not achievable on a global scale and the images were therefore divided into smaller blocks, normally based on the 1:50 000 topo-cadastral grids. These smaller individual images were then re-ortho-rectified for a perfect fit onto the cadastral information.

4.7 IRRIGATION IDENTIFICATION

4.7.1 Digitising of irrigated and other cultivated fields

Satellite images were ortho-rectified and the updated cadastral boundaries of the GIS were used as an overlay and no scale determination or further correction was necessary. The areas of irrigation and storing of water on the different dates for each property were identified using spectral analysis (highlighting areas based on their relative spectral signature). The areas identified on the satellite images were manually digitized from the images to ensure that the areas were as accurate as possible.

In the case of pivot irrigation, not all circles were classified as irrigation. By using the information obtained from the water users, the WARMS database and through visual inspection, the team tried to establish the physical number of machines and cropping pattern and classified the fields accordingly (e.g. tobacco is normally cultivated on the same field every third year).

During the linking of WARMS registration information to the digitised fields as identified from the satellite imagery, it became apparent that a lot of the registered crops (fields) could not be identified on the satellite images, especially deciduous orchards. In order to solve this problem and to ensure that the information provided to DWAF was as accurate as possible, a field visit to the area was scheduled. Please refer to item 3.2 for a discussion on the field visit.

In addition to irrigated fields, all other cultivated fields were digitised and classified as such. This was done to provide the team responsible for the updating of the hydrology and systems yield models with more accurate modelling capabilities since the characteristics of in terms of runoff etc.

vary significantly between cultivated fields and normal veldt. Maps showing the identified fields for the different dates are included in **Annexure K**.

4.7.2 Crop identification

If a water use was registered, the data obtained from the WARMS was cross-referenced with the digitised feature to establish the type of crop. If a water use was not registered, the Maize/Wheat crop combination was used until the correct information is provided by the water user through the section 35 process or as part of a late registration.

4.7.3 Irrigation system identification

If a water use was registered, the data obtained from the WARMS was cross-referenced with the digitised feature to establish the irrigation system. If the water use was not registered and it could not be identified as centre pivot irrigation, “Sprinkler: Quick Coupling” was used as substitute irrigation system until the correct information is provided by the water user through the section 35 process or as part of a late registration.

4.7.4 Irrigation volume calculation

By using the type of crop and irrigation system per identified field, the irrigation volume was calculated using the field extent and the crop irrigation requirements (see item 4.5). The calculated irrigation volumes were then captured in the custom database.

4.8 DIGITISING OF DAMS AND VOLUME DETERMINATION

The identification of storage structures and the calculation of storage capacities within the study area were critical for the calibration of the water use model and any subsequent simulations. By using aerial photographs, 1:50 000 topo-cadastral maps, satellite imagery, dam safety information, a DTM and historic survey results, the area and depth of each storage structure was determined and used to calculate the storage capacity.

If a dam was surveyed during the field surveys conducted in the two GWCAs during the 1980’s and the dam remained unchanged, the capacity calculated during the field survey was assumed to be the most accurate data and that capacity was used.

Based on survey information and visual inspection of available data, storage structures were classified as storage, weirs, pans, gravel pits or mine dams (mining evaporation dams and sewage works).

Maps showing the identified storage structures for the different dates are included in **Annexure K**.

4.9 ESTABLISHING LAWFUL WATER USE

More than 50% of the study area falls within Government Water Control Areas and Irrigation Boards while the rest is previously uncontrolled areas. In some cases the determination of lawful water use was a very complex and time-consuming task. In the case of a GWCA the water use on the date of proclamation needed to be established for each property, as it existed on **that date**. A typical problem occurred where a property falling within a GWCA had a certain "water right" on a specific date (date of proclamation of GWCA), say 1969. Since then the property was subdivided into three portions and one of these three was consolidated with another property. There was no quick fix and a timeline and the effect on water use authorisations had to be drawn up to verify the veracity of water use on an identified property.

4.9.1 Irrigation with surface water

4.9.1.1 Controlled areas

Mokolo River GWCA

The Mokolo River GWCA was established by means of proclamation no. 276 of 24 October 1969. The provisional determination in respect of that portion of the GWCA upstream of the Hans Strijdom Dam was published in the Government Gazette on 24 July 1981 (Notice no. 1531). A notice was published in terms of section 62(2F)(a)) on 11 September 1987 (Notice no. 1928) where the maximum extent of land that could be irrigated, was provided. The notice stated that a maximum of 9 150 cubic metres of public water may, if available, be used per annum for the irrigation of each hectare and this volume was used to determine the lawful water use.

If a piece of land was subdivided after the date of inclusion in the area, the owner of the original portion was authorised to determine at his/her discretion by agreement with the owner of the property subtracted, the quantity of water to be transferred to the new property. If the validation team found no agreement, the water use was temporarily apportioned according on the physical location of the irrigated fields during the field survey.

If two or more properties consolidated, the permissible uses were simply added together.

Hans Strijdom Dam Catchment GWCA

The Hans Strijdom Dam Catchment GWCA was established by means of proclamation no. 165 of 20 September 1985. A general permission in terms of section 62 (2B) (a) of the Water Act, 1956, was published in the Government Gazette on 5 June 1987 (Notice no. 1229). In terms of the general permission no new water works may be erected and no existing water work altered of enlarged for the abstraction of any public water that may be used for irrigation and/or stock drinking purposes except by virtue of an authorisation issued in terms of section 62 (2H)(a) of the Act,1956.

In respect of a piece of land with existing irrigation development, the owner of such piece of land (as registered in the office of the Registrar of Title Deeds on the date of inclusion) was provisionally entitled (until a notice was published in terms of section 62(2F)(a)), to continue by means of an existing water work with the abstraction or use of water for irrigation purposes of not more than the quantity of public water actually used for irrigation on that land during the period of twelve months immediately preceding the date of inclusion.

Permission was also granted to any person in control of a piece of land (as registered in the office of the Registrar of Title Deeds on the date of inclusion) and on which no irrigation development or less that 15 hectares of irrigation development existed, to abstract and use on such land a quantity of public water for the irrigation of a maximum of 15 hectares of the potentially irrigable area. A maximum of 9 150 cubic metres of public water may, if available, be used per annum for the irrigation of each hectare.

No water use allocations were published in terms of section 62(2F)(a) of the Act,1956, and the lawful use was therefore taken as the use that existed on the date of inclusion if the irrigated extent was more than 15 hectares, or a maximum of 15 hectares per property (as registered in the office of the Registrar of Title Deeds on the date of inclusion) if the irrigable potential existed.

The lawful annual volume was calculated by multiplying the lawful irrigation area by 9 150 m^3/annum.

If a piece of land was subdivided after the date of inclusion in the area, the owner of the original portion was authorised to determine at his/her discretion by agreement with the owner of the property subtracted, the quantity of water to be transferred to the new property. If the validation team found no agreement, the water use was temporarily apportioned according on the physical location of the irrigated fields during the field survey.

If two or more properties consolidated, the permissible uses were simply added together.

4.9.1.2 Uncontrolled areas

Areas of the catchment not included in GWCAs fell under the limitations of section 9 B of the 1956 Water Act (Act 54 of 1956) where a maximum rate of abstraction of 110 l/s from surface water resources was allowed for each property as registered with the Registrar of Title Deeds on 28 May 1975.

4.9.2 Irrigation with groundwater

Under the previous Water Act (1956), water abstracted from boreholes was regarded as private water and since the study area is not included in a Subterranean Government Water Control Area, no limitations were placed on the abstraction of water from boreholes for irrigation purposes. The lawful water use from boreholes was therefore the use that was exercised within the two years prior to the promulgation of the Act, i.e. 1 October 1996 to 30 September 1998.

4.9.3 Storing of water

4.9.3.1 Controlled areas

Mogol River GWCA

The Mokolo River GWCA was established by means of proclamation no. 276 of 24 October 1969. The provisional determination in terms of section 62 (2)(a) of the Act,1956, respect of that portion of the GWCA upstream of the Hans Strijdom Dam was published in the Government Gazette on 24 July 1981 (Notice no. 1531). A general permission in terms of section 62 (2B) (a) of the Water Act, 1956, was published in the Government Gazette on 5 June 1987 (Notice no. 1229). In terms of the general permission the construction or erection of new storage works as well as the enlargement or alteration of exiting storage works in any public stream in the area were totally prohibited except by virtue of an authorisation in terms of section 62 (2A)(a) of the Act, 1956.

Hans Strijdom Dam Catchment GWCA

The Hans Strijdom Dam Catchment GWCA was established by means of proclamation no. 165 of 20 September 1985. A general permission in terms of section 62 (2B) (a) of the Water Act, 1956, was published in the Government Gazette on 5 June 1987 (Notice no. 1229). In terms of the general permission the construction or erection of new storage works as well as the enlargement or alteration of exiting storage works in any public stream in the area was totally prohibited except by virtue of an authorisation in terms of section 62 (2A)(a) of the Act, 1956.

The limits of the general permission with regard to the erection of weirs to provide pumping wells for irrigation purposes and for limited storage for domestic use and stock-watering purposes were amended by means of proclamation no. 1636 of 4 August 1989. The previous general permission was amended by the addition of the following text *"provided that works authorisations in terms of section 62 (2H)(a) of the Act shall on application be considered by the Regional Director: Transvaal, Department of Water Affairs, Private Bag X124, Pretoria 0001, for the erection of weirs in public streams within the area up to a maximum storage capacity of 3 000 cubic metres per property with a view to the provision of pumping wells for irrigation purposes as well as limited storage for domestic use and stock watering purposes, subject to conditions the said Regional Director deems necessary"*

4.9.3.2 Uncontrolled areas

Areas of the catchment not included in GWCAs fell under the limitations of section 9 B of the 1956 Water Act (Act 54 of 1956) where storage of water was limited to 250 000 m^3 for each property as registered with the Registrar of Title Deeds on 28 May 1975.

4.10 CLASSIFICATION OF VALIDATED WATER USES

Since more than one water use may be found on any given property, scenarios arose where water users registered their entitlement to take water from a water resource correctly, but omitted to register the impeding structure on the property and/or under registered the capacity of the storage dam. Given the above, one classification per property (registration) could not yield the correct result and the categorisation was done according to the type of water use and water resource. By using these small data blocks, a general classification for each registration file consisting of combinations of the above, can be compiled at any stage.

The aim of the validation process was to establish 4 values for each identified water use namely:

- Registered use
- Lawful use
- Existing use (1996-1999)
- Current use (2005)

When these four values were known, any question relating to the water use on a specific property was answerable.

For example:

- The existing lawful use would be the lesser of Lawful use and Existing use.

- If the registered use is zero and the existing lawful use is *Q* the water user did not register his lawful entitlement *Q* and it would be classified as **unregistered**.
- If the registered volume is less than the existing lawful use, it would be classified as **possible under registration.**
- If the registered volume is equal to the existing use but the existing use is more than the lawful use, it would be classified as a **possible correct registration** but a part thereof will also be classified as **possible unlawful**.

Using various permutations, all the necessary answers pertaining to validation and lawfulness can be provided.

5 VALIDATION RESULTS

Throughout the validation process, all numerical results obtained were captured on the supporting database for use during the verification process. It is important to note that the results obtained through the validation process are all preliminary. Although the PPP went to great lengths to inform water users of the validation process there were still some users who did not respond to the invitations to participate. Only when the verification of water use has been completed, will the true extent of water use (including existing lawful use) be known.

The general conclusion following the validation process is that water use was over-registered. This can mainly be attributed to two factors. Firstly, apart form registering their current water use, some water users also registered their planned irrigation development. In many instances, water users registered their lawful water use entitlement (as published in the Government Gazette) and not their existing water use. Secondly, the registered water use sometimes reflected the general irrigation practice over a certain period and not the annual use. An example is the case where a water user has one twenty-hectare centre pivot that is only planted in summer. The water user either planted maize or tobacco or groundnuts (total of 20 hectares per annum). During the completion of the registration forms the water user registered three crops, each with an extent of 20 hectares. The extent of the registered crops in WARMS therefore amounted to 60 hectares, which is incorrect.

Summaries of the validation results are presented in the following sections.

5.1 IRRIGATION

A summary of the validated water uses in terms of **crop hectares** under irrigation per annum is presented in Table 2.

Table 2: Validation results – Irrigated crop extent (ha)

Water resource	Lawful use (ha)	Field surveys 1985 (ha)	Existing use 1998/99 (ha)	Current use 2004 (ha)	Existing lawful use (ha)	Registered use (ha)
Surface water	23 074.77	12 264.17	9 109.73	8 114.06	8 010.92	13 115.4
Groundwater	839.11	245.70	839.11	949.03	839.11	2 542.0
Scheme	3 468.44	1 557.08	1 487.19	1 072.00	3 468.44	3 468.4
Total	**27 382.32**	**14 066.95**	**11 436.03**	**10 135.09**	**12 318.47**	**19 125.8**

A summary of the validated water uses in terms of irrigation volumes per annum is presented in Table 3.

Table 3: Validation results – Annual irrigation volumes (m^3)

Water resource	Lawful use (ha)	Field surveys 1985 (ha)	Existing use 1998/99 (ha)	Current use 2004 (ha)	Existing lawful use (ha)	Registered use (ha)
Surface water	211 134 146	87 074 400	52 221 026	47 909 118	46 155 099	59 956 843
Groundwater	4 979 839	1 744 470	4 979 839	5 676 070	4 979 839	10 397 567
Scheme	24 279 080	11 406 275	10 961 911	7 875 730	24 279 080	24 279 080
Total	**240 393 065**	**100 225 145**	**68 162 776**	**61 460 918**	**75 414 018**	**94 633 490**

Based upon the provisions contained in the two Government Water Control Areas, the scheduled water within the Irrigation Board and the unrestricted use of borehole water, the previous Act allowed for the taking of some **240 million cubic metres** per annum from the surface and underground water resources. Refer to item 4.9 for the explanation of lawful water use.

When the existing lawful use from surface water (46 155 099 m^3/a) is compared with the 1998/99 water use (52 221 026 m^3/a) it is evident that water users were abstracting some 6 million m^3/a more than they were lawfully entitled to. Although the water use decreased between 1998/99 and 2004, the current annual abstraction from surface water resources (47 909 118 m^3/a) is some 1.7 million m^3 more that the existing lawful entitlement.

In terms of ground water resources the current annual abstraction of 5 676 070 m^3/a is some 700 000 m^3 more that the existing lawful entitlement of 4 979 839 m^3/a.

It is interesting to note that the actual extent under irrigation from surface water resources decreased by some 3 600 ha or 35 million m^3/a between the mid 1980's and 1998/99. This can be attributed to the fact that irrigators riparian to the river historically relied on natural runoff and were able to cope with the natural variability of the flow. The increased use of water for irrigation also had a huge effect on the flow regime of the river and the only way they could overcome this problem was to increase their storage in order to stabilise supplies. The construction of new dams was however prohibited following the proclamation of the two Government Water Control areas which in effect, blocked further development. The higher risks associated with the unstable flow combined with other factors such as higher agricultural input costs, etc. led to a marked change in agricultural practices in the area. Established irrigation farms were consequently converted to cattle ranches while other farmers switched from crop to game farming.

The detail breakdown of the information presented in the previous two tables is included in **Annexure G** and is also discussed under items 6.4.8 to 6.4.10.

A summary of the water use classification in terms of irrigation volumes per annum is presented in Table 4.

Table 4: Validation results – Classified water use volumes (m^3)

Water resource	Correctly registered	Over registered	Under registered	Existing lawful use	Possible unlawful use in 1998/99	Possible unlawful use in 2004
Surface water	31 301 502	28 655 341	14 853 597	46 155 099	6 241 731	7 432 047
Ground water	3 786 474	7 327 580	1 909 852	4 979 839	0	1 166 734
Scheme	24 279 080	0	0	24 279 080	0	0
Total	**59 367 056**	**35 982 921**	**16 763 449**	**75 414 018**	**6 241 731**	**8 598 781**

From the table above it is evident that the net result of the validation process is an over registration of some 19.2 million m^3/a while possible unlawful use during the qualifying period amounted to some 6.2 million m^3/a. The possible unlawful use in 2004 increased to some 8.6 million m^3/a.

A detailed schedule of all the classified water uses per property is included in **Annexure J**.

5.2 STORAGE

A summary of the validated storage is presented in Table 5.

Table 5: Validation results - Storing of water

Type		Field surveys 1985	Existing use 1998/99	Current use 2004	Possible existing lawful
Weir	Number	147	156	156	148
	Volume (m^3)	2 453 734	2 652 150	2 675 209	2 584 214
	Area (m^2)	1 841 698	2 026 367	2 050 319	1 930 552
Storage	Number	858	1 020	1 066	872
	Volume (m^3)	14 766 951	17 878 566	20 680 111	17 585 053
	Area (m^2)	9 832 062	11 551 762	12 380 690	10 191 943
Pan	Number	68	68	68	68
	Volume (m^3)	693 108	693 108	693 108	693 108
	Area (m^2)	1 387 978	1 387 978	1 387 978	1 387 978
Gravel pit	Number	91	91	91	91
	Volume (m^3)	2 427 551	2 429 741	2 427 551	2 429 742
	Area (m^2)	1 607 216	1 607 216	1 605 390	1 607 216
Mine	Number	35	36	37	37
	Volume (m^3)	4 618 856	4 654 788	4 658 249	4 658 249
	Area (m^2)	2 258 944	2 288 887	2 291 771	2 291 771
TOTAL	**Number**	**1 199**	**1 371**	**1 418**	**1 216**
	Volume (m^3)	**24 960 200**	**28 308 353**	**31 134 228**	**27 950 366**
	Area (m^2)	**16 927 898**	**18 862 210**	**19 716 148**	**17 409 460**

From the detailed analyses an increase in the total storage since 1985 was detected. The total storage in 1985 was some 24 960 200 m^3. During 1998 this storage increased to 28 308 353 m^3. The latest storage identified in 2004 is some 31 134 228 m^3. The preliminary existing lawful storage is some 27 950 366 m^3.

While some of the increases in storage were lawful there is currently some 10.2 % or some 3 183 862 m^3 of the current storage development that may be unlawful.

A detailed schedule of all the classified water uses per property is included in **Annexure J**.

5.3 GIS COMPILATION

All information used, compiled and generated during the project were standardised and linked to the GIS. The GIS information was provided in Arc View shape file format and included inter alia:

- Farm boundaries
- Property boundaries (validation summaries were linked to each individual property)
- Populated places, Towns and Municipal boundaries
- Government Water Control Areas and Irrigation Board boundaries
- Quaternary catchments (validation summaries were linked to each individual catchment)
- Sub catchments (validation summaries were linked to each individual sub catchment)
- Rivers
- Satellite images
- 1:50 000 topo cadastral reference grid
- Identified land use for each time period (irrigated and cultivated fields)
- Identified storage for each time period

6 IRRIGATION WATER DEMAND

6.1 SUMMARY

In this part of the study, the theoretical water demand of the identified irrigation development was determined. Following this, the actual practical situation was assessed, taking cognisance of on-farm irrigation system efficiency, the effect of droughts on the theoretical irrigation demands and the expected return flows from irrigated fields back to the water resource(-s).

The quaternary catchment was used as the basic unit for output in the study. On request of the modellers, the quaternary catchments were subsequently divided into smaller sub catchments for modelling purposes. Time series, on a monthly resolution, were generated for the theoretical irrigation demands and the practical (“actual”) demands, based on both a growth model and a fixed model of irrigation development in every catchment.

In the growth model, the start date of the available rainfall record was used as the base date of the development. From this point the irrigation development was increased up to the date of the present assessment. The growth in irrigation area is not necessarily linear, and in this model it was based on discovered external influences, such as the introduction of awareness programs, changes in cropping patterns, introduction of electricity and the declaration of government water control areas.

In the fixed model, the current irrigation development was retained as fixed over the total time span of the rainfall record, and the time series of demand were analysed statistically to discover to what level of assurance the current irrigation development can be entertained. A quota per field area, based on an acceptable level of assurance, was determined for every catchment from a statistical analysis of the long term irrigation requirements as determined from the fixed model.

This model also calculated the abstraction rate that should be allowed in each quaternary catchment.

The typical monthly crop factors for use with Penman-Monteith ET_0 reference evaporation were also calculated by using the fixed model.

6.1.1 Representative crop

The WARMS database of DWAF was scrutinised to determine the type of crop, the irrigation system, the area, the water source and the quaternary catchment of each registered irrigation field in the project area. This data was further refined after consultation with the water users during field visits.

The aim of this exercise was to facilitate the definition of a representative crop that mimics the effect of all the crops and irrigations systems within a particular quaternary catchment.

6.1.2 Rainfall

Rainfall records were incorporated in the irrigation demand model to determine a time series of irrigation demands. The extended records, as provided by the modelling team, were used.

The rainfall records were converted into records of effective rainfall (i.e. effective for irrigation fields) by using the methods used in the SAPWAT program, as well as the methods recommended by the FAO. These records were used in conjunction with the SAPWAT model to determine the irrigation demands.

6.1.3 Evapotranspiration

The monthly Penman-Monteith evapotranspiration grids available from the *South African Atlas of Climatology and Agrohydrology (Schulze et al 2006)* were analysed to determine the representative monthly evapotranspiration per quaternary catchment. From these values, the average and median daily evaporation values were generated as inputs into the SAPWAT model.

6.1.4 SAPWAT Model

Using the median rainfall records (actual, not effective) together with the daily evapotranspiration records, a driver climatic station was generated for each quaternary catchment. By using this approach, the number of usable SAPWAT climate stations was increased from the original 350 to some 1946 countrywide, without sacrificing any accuracy. In the Mokolo catchment, SAPWAT originally provided for only one station, namely Vaalwater. The use of a driver station per quaternary catchment resulted in nine climate stations for this catchment.

Only the basic front end of the SAPWAT model was used in this exercise. No attempt was made to improve the generic data used in the basic front end with further refined soil data, rooting depths, scheduling techniques or refined irrigation practises. The results from the basic front en analysis were captured from the text files that the SAPWAT model generated. Data for both “with rain” and “without rain” were captured and further analysed.

6.1.5 Irrigation demand records

A model was set up to deliver the required irrigation demand records. In the first part of the model, irrigation fields with the same crop and irrigation system were lumped together per quaternary catchment. Where different benchmark data, such as data from previous field surveys were available, such data were also included in the model. SAPWAT was then used to determine the irrigation requirements, both with and without taking rainfall into account.

The SAPWAT results were fed back into the demand model, resulting in a monthly irrigation requirement for every crop/system combination in each quaternary catchment. The results with the effect of rainfall included were used to determine the volumes required for the definition of the existing lawful water uses (based on the median annual rainfall. The results excluding rainfall were subsequently used in the model to determine the monthly irrigation demand time series and to quantify required abstraction rates.

The record generation part of the model used the “SAPWAT without rainfall” results together with the effective rainfall records generated earlier to determine the monthly records of irrigation demands. This part of the model allowed for the generation of different sets of records for different water sources or water resources. Different records were generated for surface water, borehole water and scheme water. A complete set of records was generated for each quaternary catchment. Such a set of records consists of results per water resource, both for the growth model and fixed model described earlier.

6.1.6 Actual irrigation usage

Recognising that during periods of water scarcity the total irrigation demands will most probably not realise as irrigators postpone planting dates until the first rain falls, or even not irrigate at all during a particularly dry year, it was deemed necessary to reduce the demands to be balanced with the expected irrigation practices. The model took this into account by calculating a "drought reduction factor" and subsequently created "actual" irrigation usages based on expected irrigation patterns. The algorithm for this process was based on the mean monthly and the mean annual rainfall in the respective quaternary catchments.

The model generated time series of actual irrigation usage, both for the growth model and fixed model for each quaternary catchment.

It must be stressed that this approach has only been thought through for irrigation in the catchments of the northern part of the country (north of the Orange River). In these parts of the country, irrigation is normally supplemental to rainfall, as the extent of the rainfall is such that it should normally be taken into account. In other parts of the country where rainfall is lower or more erratic, a different approach may be contemplated.

6.1.7 Irrigation efficiency

The output of this part of the study was the evaluation of the weighted efficiencies of infield irrigation practices. The results of this output can be used in the assessment of the existing irrigation practices in a particular quaternary catchment. Low efficiencies may point to areas where intervention may be necessary, while high efficiencies may indicate the awareness of the irrigators of the responsible use of water.

A series of "what if" questions can be addressed, such as "what if a target irrigation efficiency of 85% is encouraged in the catchment?"; "what if the average irrigation efficiency is increased by 10%?" The answers to these and similar questions can be expressed in time series records that may be used in catchment models to describe the overall effect thereof on the available water supplies in that catchment.

6.1.8 Abstraction rate

This output of the study was the required abstraction rate in l/s/ha for each quaternary catchment. These results may be used as licence conditions during future licensing of water use in the area.

6.1.9 Crop factors

The output of this part of the study was the calculated Penman-Monteith crop factors for the representative crop, planting dates and irrigation strategies per quaternary catchment.

6.1.10 Return flows

This output was the evaluation of the return flows generated from the irrigated fields. The return flows were defined as a portion of the total in-field irrigation losses. The weighted average results for every crop/system combination were fed back into the demand model, resulting in a monthly return flow time series for each quaternary catchment.

6.1.11 Model interface

The final output of the model was a spreadsheet interface that allows the user the input of variables, such as irrigated areas, return flow fractions and return flow limitations. It also allows for the calculation of proposed irrigation quotas per field area. The generated time series for any combination of the parameters are included in the model.

6.2 DETAILED REPORTING

6.2.1 Representative crop

6.2.1.1 The **first task** in identifying the representative crop was the analysis of the depth of irrigation required for the crop/system combination in the relevant quaternary catchment. The process is shown schematically in **Figure 3**:

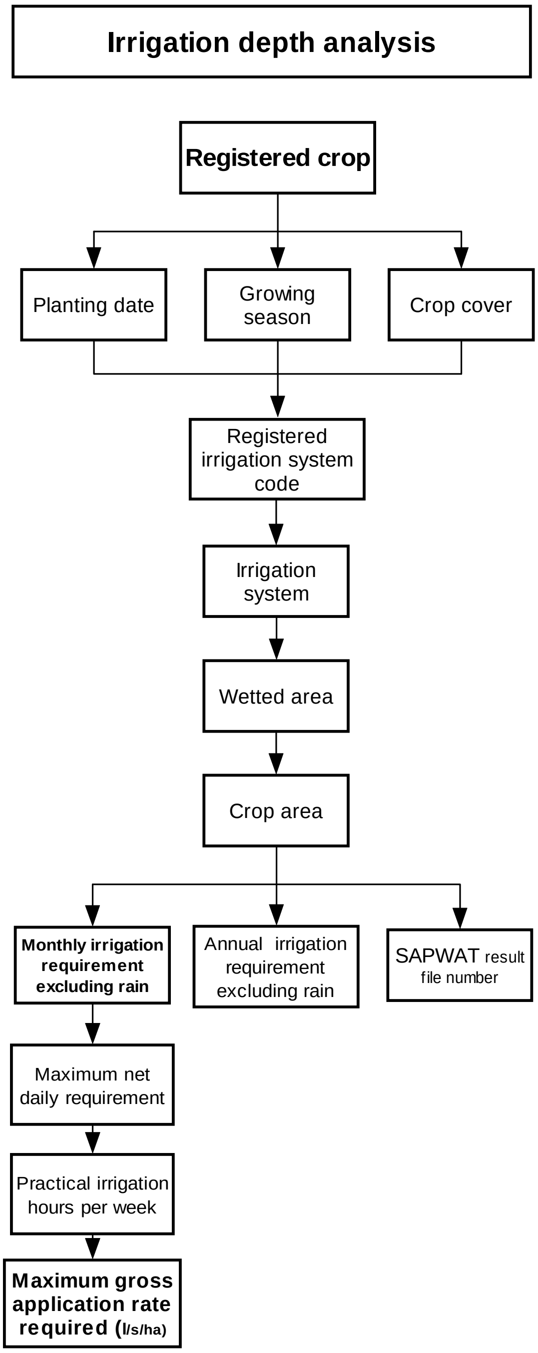


Figure 3: Irrigation depth analysis

6.2.1.2 The latest registered information, including information obtained from irrigators during field visits was used to do a normal SAPWAT determination of the irrigation requirements. For each unique crop/irrigation combination, a SAPWAT calculation was completed. During this process, details pertaining to the crop name, planting date, length of the growing period, season during which the crop is cultivated, crop cover, irrigation system and wetted area were fed into SAPWAT. The resultant text file created by SAPWAT named "summary.dat" was then renamed with a numerical prefix and the suffix "csv" and the renamed file saved with the data of that particular catchment. A typical file name would be "23.csv", which is the file of the 23rd crop combination for that particular catchment.

6.2.1.3 The data from the said text file was subsequently imported into a spreadsheet for further analysis. Data for both rainfall included and rainfall excluded were imported. The two-sheet spreadsheet was further populated with the registered crop area under irrigation for every crop combination. This spreadsheet was generically named to reflect the relevant quaternary catchment. A typical name would be "Registered A42A.xls", where A42A is the quaternary catchment.

6.2.1.4 The first sheet on the said spreadsheet computes the total annual depth of irrigation required for each crop combination. It furthermore computes the maximum net daily depth of irrigation required both for "with rain" and "without rain". These depths are then converted to a required continuous abstraction rate, expressed in litres per second per hectare. The net required abstraction rate is then converted to a practical value by limiting the total available hours per week from 168 to 144. The resultant practical abstraction rate (for the case that excludes rainfall) is the suggested allowable abstraction rate for licensing purposes.

In the model, these calculations are included in a sheet called **Reg_Crops_mm** (and **Surv_Crops_mm** where survey data was available).

6.2.1.5 The **second task** in the identification of the representative crop was an analysis of the irrigation volumes required. This process is shown schematically in **Figure 4**:

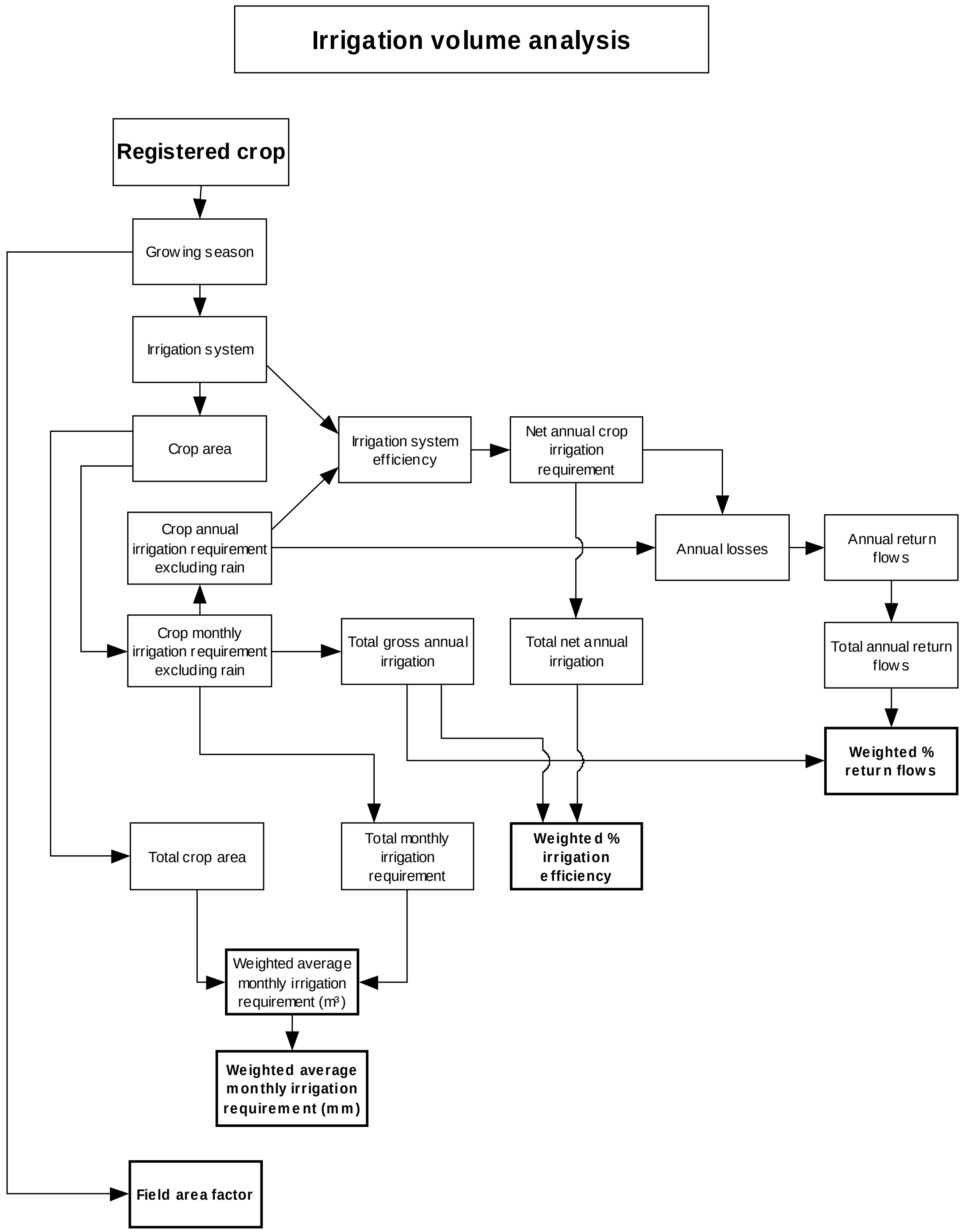


Figure 4: Irrigation volume analysis

6.2.1.6 This task follows on the previous task. As SAPWAT does not provide for the analysis of a time series of records, it was necessary to create a demand excluding rainfall, from which the effective rainfall record can be subtracted, resulting in a time series of irrigation demands. The shortcoming in this method is that the irrigation demands are quantified using average values of evaporation. Although not strictly accurate, this is presently the best approach available, as no representative time series of evaporation is yet available. The same crop and other data as described above, is used in this task. The crop area was multiplied by the depth of irrigation required to obtain monthly volumetric values based on the requirement with rainfall excluded.

6.2.1.7 The volumetric demands for every crop combination were calculated and aggregated per month. The monthly totals were then divided by the total crop areas, resulting in a weighted average monthly demand per crop hectare. These results were then converted back to irrigation depths in millimetre per month for further use in the model. These results mimic the monthly irrigation demand (rainfall excluded) for all of the crop combinations occurring within the relevant quaternary catchment. It therefore defines a single crop representing the effect of all crop combinations. This imaginary crop is called the **representative crop**.

6.2.1.8 The seasonal classification of the crop combination made it possible to determine the actual field sizes. Although for all of the permanent crops the field sizes equal the crop areas, this is not necessarily true for seasonal crops. Some of the winter crops are cultivated on the same fields that were used for summer crops. In order to express the irrigation demand in terms of a quota per field area, it was deemed necessary to determine the actual field sizes as accurately as possible. In the model the smallest of either the winter or summer crop areas were deemed also to be irrigated during the alternate season. In the whole of the project area it was found that the winter areas were always smaller than the summer areas. This resulted in the assumption that the field areas might be calculated by adding the summer and permanent areas. This resultant field area was called the “quota area” in the model. A further factor, called the “quota factor” was developed to facilitate further calculations in the model. The quota factor was calculated by dividing the total crop area by the quota area. In any particular quaternary catchment dividing the total crop area by the quota factor will thus result in the actual field area for that catchment. Dividing the irrigation demand by the quota factor will result in the demand per field hectare.

6.2.1.9 The SAPWAT irrigation demands include the effect of the efficiency of the relevant irrigation systems. In order to determine the net crop requirement, this task also analysed the effect of the system efficiencies. The irrigation demands were multiplied by the generic system efficiencies contained within SAPWAT, resulting in the crop (net) water requirements. The time series of annual irrigation demands were analysed to obtain the time series of crop water demands. Aggregating the latter time series and dividing it by the aggregated irrigation water demands resulted in the weighted average irrigation efficiency within the catchment. This representative efficiency was subsequently used in the model used to calculate the representative crop evapotranspiration factor (Etc).

6.2.1.10 The final part of this task analysed the potential return flows from the crop areas. The hypothesis was that 50% of the difference between the irrigation demand and the crop water demand will be available as return flows. These calculated values were once again aggregated on an annual basis. Dividing the aggregated return flows by the total crop area within the relevant catchment resulted in a weighted return flow percentage per crop hectare. This value was used further down in the model to determine a time series of monthly return flows.

In the model, these calculations are included in a sheet called **Reg_Crops_m3** (and **Surv_Crops_m3** where survey data was available)

6.2.2 Generation of time series records

6.2.2.1 The defining driver for all of the time series records generated by the model was the rainfall record for each quaternary catchment. These records were obtained from WRP. The full set of records used contained monthly rainfall records for each catchment, stretching from September 1920 to October 2004.

6.2.2.2 The process of converting the rainfall records for purposes of this model is shown in **Figure 5**:

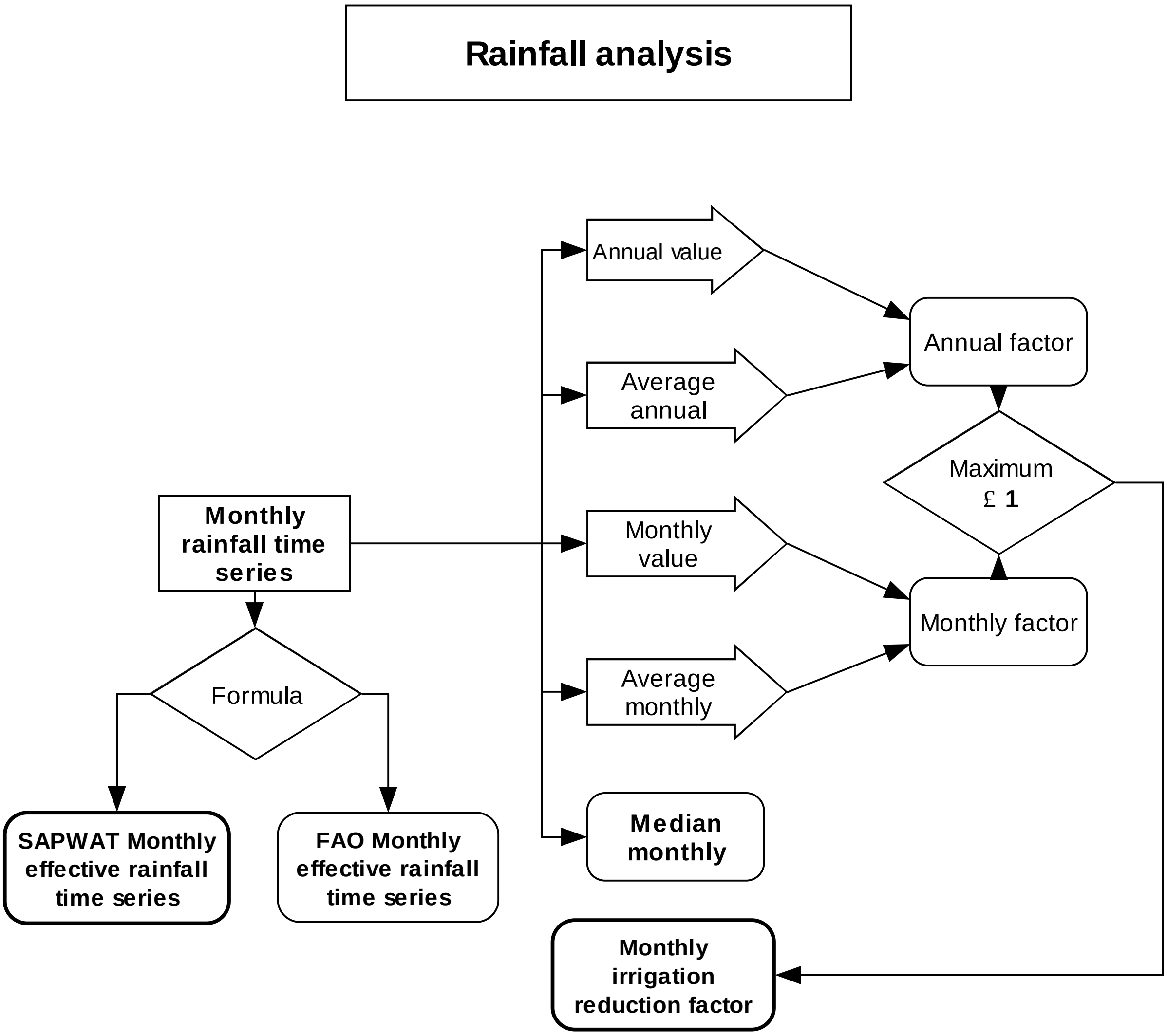


Figure 5: Rainfall analysis

6.2.2.3 The **first task** in this process was to convert the monthly rainfall values to effective rainfall (effective for irrigation). Two approaches were used during this task. Firstly, a formula developed by the FAO was used. This formula only operates on the actual rainfall and does not take cognisance of the available water retaining capacity of the soil profile. This formula is:

Effective Rainfall = (0.6 * Total Rainfall) - 10 ... (Total Rainfall < 70 mm)

Effective Rainfall = (0.8 * Total Rainfall) - 24 ... (Total Rainfall > 70 mm)

The FAO formula was only used for comparative reasons and is not discussed further.

6.2.2.4 The formula used by SAPWAT was discussed with the developers of the program. The relevant reference literature is found in the minutes of meetings of the steering committee responsible for the development of SAPWAT. We accept the accuracy and theoretical basis of the formula. This formula does take cognisance of the available water retaining capacity of the soil in that it evaluates the monthly evapotranspiration. In SAPWAT the maximum monthly evapotranspiration considered is limited to 75 mm. This formula is:

$$r_e = ET\left(-0{,}001\frac{r^2}{ET} + 0{,}025\frac{r^2}{ET^2} + 0{,}0016r + 0{,}6\frac{r}{ET}\right) \text{ where } ET \text{ is limited to 75 mm}$$

In this formula: r_e = the effective monthly rainfall
r = the actual monthly rainfall
ET = the monthly crop evapotranspiration

A time series of effective rainfall was subsequently compiled by using this equation, and using the actual rainfall for every month of the record plus the weighted monthly crop evapotranspiration.

6.2.2.5 The drought reduction factors were then calculated as the **second task**. The algorithm for this process was based on the actual and mean monthly and the actual and mean annual rainfall in the respective quaternary catchments. For every month of the time series, the rainfall for that particular month was divided by the mean rainfall for that particular month over the whole time series. Should this result be greater than 1, it was limited to 1 and memorised. A result smaller than 1 was also put into memory. While evaluating that particular month, the actual rainfall for the hydrological year in which that specific month falls, was divided by the mean annual rainfall for all hydrological years of the time series. Once again, this result was limited to a maximum of 1. These results were then compared with the monthly results held in memory. The model then defines the **drought reduction factor** for that particular month as the larger of these two values.

The reasoning behind this algorithm is that a single dry month in an otherwise normal or wet year will not limit the planting of irrigation crops. The actual planting date may be postponed by a month or two, or alternative crops may be planted should the year turn out to be normal or wet. During a particularly dry year, a smaller area of planted crops, or even no planting at all, may reasonably be expected.

This approach obviously does not take into account the irrigation of permanent crops such as orchards. Care should be taken not to use a drought reduction factor that mimics actual irrigation use at levels lower than those required for the permanent crops. No such problem was encountered in the study area.

The drought reduction factors were used deeper down in the model to reduce the theoretical irrigation demands to actual (drought restricted) irrigation demands.

In the model these calculations are included in a sheet named **Rain**.

6.2.2.6 The **third task** was to develop time series based on a fixed area of irrigation. The gross monthly irrigation requirements (mm) for the representative crop, excluding rainfall, are used as the point of departure. For every month of the time series, the effective rainfall is the subtracted from the gross irrigation requirement for that month. These results were limited to a minimum of 0 and are included under a heading of **Net irrigation requirements (mm)** in a sheet named **Flow_Fix_m3**.

The total annual irrigation requirements obtained from this time series were then analysed statistically to obtain the annual irrigation depth that will satisfy the demands at different levels of assurance. The depths were converted into a volume per field area by multiplying the crop area with the quota factor described earlier. These results are shown to the right of the table containing the net irrigation requirements.

The time series for the depth of irrigation requirements was then converted to a time series of the volume of irrigation requirements. This is shown under the heading **Net irrigation requirements (m^3)**.

The next time series in the model, under the heading **Drought reduction factor included** is the result when the net irrigation requirements (m^3) are multiplied with the drought reduction factor calculated earlier.

In the last part of the sheet **Flow_Fix_m3** the return flows are quantified. The weighted average return flow percentage is multiplied by the corresponding monthly irrigation requirements. In the model, the return flows during drought restricted months is reduced by multiplying the results with a factor of 0,75. This is done in order to appreciate higher losses during severe droughts and also to cater for drier soil profiles, holding back more water than during wetter periods.

The results of the calculations done on the sheet **Flow_Fix_m3** are carried over to a sheet called **Flow_Fix_Record**, and are portrayed in a format that is user friendly for further modelling purposes. The values are expressed in million cubic metres under the headings **Net irrigation requirements (10^6m^3)**, **Drought reduction factor included** and **Return flows** respectively.

6.2.2.7 The **fourth task** was to develop the growth model that mimics the growth in irrigation from the base date of October 1920 to the last date used in the model, namely September 2004.

Benchmark data were available for the year 1970 (first control instituted), 1984/1985 (filed surveys conducted in the area), 1990 (satellite imagery), 1998 (validated registration) and 2004 (satellite imagery).

The growth model is based on the following assumptions:

Range	Assumption
1920 - 1970	Exponential growth to weighted% of 1985 figure
1971 - 1985	Linear growth to 1985 figure
1986 - 1998	Linear growth to 1998 figure
1999 - 2004	Linear growth to 2004 figure

For the period 1920 to 1970, an exponential relationship was developed to show low initial growth, followed by increased growth in the last ten years before the first formal government water control was instituted.

The formula developed is:

$$y = b \times m^{yearnumber} \times \frac{Area_{Control}}{Area_{Survey}}$$

Where b = 0.774 and m = 1.1 (year number is 1 in 1920 and 51 in 1970)

The compilation of the growth model is included in a sheet called **Grow_Model** in the model.

6.2.2.8 The **fifth task** was to develop time series of irrigation demands based on the growth in irrigation areas over the whole period of the available record. This task follows the same procedures described earlier for a fixed area of irrigation, except that the calculations are based upon a growing area of irrigation.

6.2.2.9 The **sixth task** was to reverse engineer the calculations done earlier to obtain representative monthly crop factors for the representative crop.

In this task the calculated crop evapotranspiration Et_c as calculated by multiplying the monthly irrigation requirement by the system efficiency, was compared with the Penman-Monteith evaporation. The following relationship was used:

$\mathbf{Et_c = K_c * Et_0}$, where Et_c is the crop evapotranspiration, Et_0 is the Penman-Monteith evaporation and K_c is the representative crop factor.

The K_c-values are shown in sheet **ETo** in the model.

Graphical results showing the time series for the fixed area model is included in sheet **Fix_Model_Graph** and that for the growing area model is included in sheet **Grow_Model_Graph** of the model.

6.3 MODEL INTERFACE

A user friendly model interface was developed for each quaternary catchment. This interface allows the user to evaluate all aspects described in this part of the report and facilitates the development of different time series, as required by the user.

The model interface is contained in a sheet called **Variables**. The input structure was designed so that the user can input areas for both the growth model and the fixed area model. The left hand part of the input table contains the data used in the scenario that the user wants to analyse, while the right hand part contains the data found under our assignment. A set of radio buttons was developed to facilitate the quick evaluation of different alternatives for water resources and crop seasons.

6.4 RESULTS

The detailed results of this part of the study are contained in **Annexures G & H** of this report. The following results highlight some of the findings:

6.4.1 Rainfall

A summary of the mean (average) annual rainfall in mm per quaternary catchment is:

Table 6: Mean annual rainfall

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Tot
A42A	50	99	112	121	104	80	42	14	6	4	5	13	**650**
A42B	50	100	113	125	110	86	41	14	6	4	5	13	**666**
A42C	49	97	111	126	109	85	41	12	6	6	5	14	**660**
A42D	50	101	114	126	111	84	44	15	6	4	5	13	**674**
A42E	44	89	101	113	96	77	38	13	5	4	4	13	**598**
A42F	43	85	98	104	96	72	37	13	5	3	3	12	**570**
A42G	40	79	92	104	93	70	32	12	4	3	3	11	**545**
A42H	37	75	89	104	83	63	32	11	4	3	3	11	**515**
A42J	31	61	75	85	69	53	27	9	4	2	2	8	**427**

The calculated mean annual effective rainfall (that amount of rainfall that enters into the soil profile and is available for use by the crop) is:

Table 7: Mean annual effective rainfall

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Tot	% of rain
A42A	34	63	71	75	63	52	28	9	4	3	3	9	**414**	63.6%
A42B	34	64	71	76	67	74	34	11	4	3	3	9	**450**	67.5%
A42C	33	62	69	77	68	60	28	8	4	4	3	9	**424**	64.2%
A42D	34	64	71	77	77	88	52	12	4	3	3	9	**494**	73.3%
A42E	30	57	64	69	79	60	29	9	3	3	2	9	**416**	69.6%
A42F	29	55	62	66	59	52	33	10	3	2	2	8	**381**	66.8%
A42G	27	52	59	66	57	44	21	8	2	2	2	7	**347**	63.8%
A42H	25	49	57	65	51	46	23	8	3	2	2	7	**337**	65.5%
A42J	21	40	49	55	44	34	17	6	2	1	2	5	**277**	64.9%

6.4.2 Average annual irrigation requirements

The following table shows the average annual irrigation requirements in addition to rainfall in m³ per crop ha:

Table 8: Average annual irrigation requirements

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Tot	per field ha
A42A	916	435	782	547	49	3	12	44	198	266	440	671	**4 362**	6 101
A42B	641	469	836	569	48	2	8	25	196	278	489	672	**4 231**	6 077
A42C	508	319	635	411	34	19	47	133	280	360	505	537	**3 788**	5 230
A42D	484	196	387	228	0	0	0	0	196	359	563	646	**3 059**	5 529
A42E	1 291	753	757	15	0	2	2	11	68	197	316	856	**4 267**	5 732
A42F	987	535	958	766	5	1	1	3	185	269	465	623	**4 797**	7 091
A42G	855	965	1 308	679	143	87	118	156	193	244	344	386	**5 478**	5 869
A42H	973	701	1 049	465	102	10	36	72	216	280	491	590	**4 985**	7 264
A42J	1 025	1 009	1 222	956	365	189	180	192	246	288	439	530	**6 641**	8 667

6.4.3 Irrigation efficiency and return flows

The calculated representative irrigation efficiencies and return flows are:

Table 9: Irrigation efficiency and return flows

	Efficiency	Efficiency	Return flow	Return flow
A42A	83.01%	76.84%	8.49%	11.58%
A42B	83.09%	79.08%	8.45%	10.46%
A42C	82.88%	78.95%	8.56%	10.53%
A42D	84.29%	81.58%	7.85%	9.21%
A42E	83.85%	80.10%	8.08%	9.95%
A42F	84.91%	79.86%	7.55%	10.07%
A42G	88.10%		5.95%	
A42H	71.21%		14.39%	
A42J	84.29%		7.86%	

6.4.4 Required abstraction rates

The abstraction rates in litres per second per hectare required to satisfy the peak irrigation demands are:

Table 10: Abstraction rates to satisfy peak irrigation demands

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Max
A42A	1.14	1.17	1.42	1.42	1.15	0.83	0.62	0.70	0.57	0.51	0.74	1.16	**1.42**
A42B	0.85	1.06	1.35	1.36	0.82	0.80	0.60	0.56	0.46	0.48	0.82	1.09	**1.36**
A42C	0.86	0.99	1.15	1.15	0.87	0.79	0.63	0.68	0.59	0.58	0.72	0.90	**1.15**
A42D	0.87	0.86	1.07	1.09	0.79	0.66	0.34	0.42	0.37	0.40	0.63	0.78	**1.09**
A42E	1.02	1.15	1.33	1.34	1.06	1.20	0.96	0.88	0.44	0.55	0.61	0.91	**1.34**
A42F	0.94	1.22	1.40	1.42	1.14	1.14	0.89	0.78	0.43	0.55	0.96	1.18	**1.42**
A42G	0.78	0.94	1.17	1.19	0.76	0.75	0.56	0.43	0.34	0.42	0.75	0.91	**1.19**
A42H	1.10	1.53	1.58	1.61	1.37	1.18	0.92	0.72	0.51	0.46	0.91	1.25	**1.61**
A42J	1.29	1.60	1.55	1.58	1.10	0.92	0.65	0.63	0.52	0.45	0.75	1.24	**1.60**

6.4.5 Proposed irrigation quota

The proposed irrigation quotas based on cubic metres per field hectare per annum are:

Table 11: Proposed irrigation quotas

	Annual m^3/ha
A42A	6 705
A42B	6 635
A42C	5 784
A42D	6 031
A42E	6 075
A42F	7 776
A42G	6 265
A42H	7 880
A42J	9 150

6.4.6 Crop factors

The crop factors to be used with the Penman-Monteith evaporation are shown in the following table:

Table 12: Crop factors

		Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
A42A	**Eto**	147.77	150.59	158.19	158.15	134.10	133.24	105.71	89.53	75.58	79.99	101.73	128.97	**1 463.54**
	1985 Kc	0.73	0.97	1.08	0.66	0.24	0.20	0.21	0.25	0.26	0.25	0.23	0.42	**0.51**
	1998 Kc	0.74	0.64	0.86	0.75	0.31	0.10	0.09	0.09	0.26	0.30	0.39	0.50	**0.47**
A42B	**Eto**	149.32	153.50	160.43	161.70	136.29	136.38	108.74	93.68	79.82	84.26	104.96	130.60	**1 499.68**
	1985 Kc	0.60	0.77	1.03	0.88	0.33	0.11	0.10	0.10	0.20	0.24	0.31	0.39	**0.48**
	1998 Kc	0.58	0.66	0.87	0.75	0.28	0.07	0.06	0.06	0.24	0.30	0.41	0.49	**0.44**
A42C	**Eto**	148.67	152.40	159.49	159.72	134.73	134.84	107.77	92.62	79.01	83.20	103.96	129.97	**1 486.37**
	1985 Kc	0.54	0.66	0.87	0.71	0.27	0.21	0.21	0.26	0.33	0.36	0.35	0.37	**0.46**
	1998 Kc	0.50	0.56	0.76	0.66	0.25	0.18	0.17	0.19	0.34	0.39	0.43	0.41	**0.43**
A42D	**Eto**	148.20	151.85	159.15	161.76	136.31	136.03	107.28	92.79	78.17	83.25	103.81	129.55	**1 488.15**
	1985 Kc	0.50	0.53	0.79	0.75	0.29	0.06	0.06	0.06	0.26	0.33	0.40	0.40	**0.41**
	1998 Kc	0.50	0.47	0.63	0.54	0.00	0.00	0.00	0.00	0.25	0.39	0.49	0.49	**0.34**
A42E	**Eto**	150.78	154.10	161.44	162.37	136.94	137.39	109.45	95.16	80.84	85.87	106.26	131.87	**1 512.48**
	1985 Kc	0.85	0.79	0.84	0.36	0.14	0.13	0.12	0.13	0.18	0.28	0.32	0.58	**0.43**
	1998 Kc	0.92	0.78	0.79	0.23	0.07	0.06	0.03	0.03	0.09	0.22	0.27	0.61	**0.39**
A42F	**Eto**	155.27	157.99	166.90	169.78	144.29	143.90	113.15	99.30	83.00	89.58	110.06	135.80	**1 569.02**
	1985 Kc	0.64	0.89	1.11	0.87	0.26	0.19	0.18	0.20	0.21	0.21	0.22	0.32	**0.50**
	1998 Kc	0.73	0.63	0.86	0.77	0.12	0.03	0.01	0.01	0.22	0.27	0.38	0.45	**0.42**
A42G	**Eto**	156.33	159.78	168.37	170.99	146.13	145.48	114.75	100.70	84.07	90.39	110.93	136.20	**1 584.10**
	1998 Kc	0.66	0.86	1.04	0.73	0.39	0.26	0.22	0.20	0.23	0.25	0.29	0.30	**0.50**
A42H	**Eto**	156.84	160.53	169.45	171.89	147.57	147.14	115.98	101.88	85.25	91.22	111.91	136.90	**1 596.57**
	1998 Kc	0.60	0.61	0.78	0.54	0.28	0.07	0.08	0.09	0.21	0.24	0.33	0.36	**0.38**
A42J	**Eto**	159.56	164.43	174.49	177.47	153.94	153.14	120.40	104.76	88.31	93.14	114.54	139.51	**1 643.70**
	1998 Kc	0.67	0.76	0.87	0.76	0.46	0.29	0.24	0.20	0.26	0.28	0.34	0.36	**0.50**

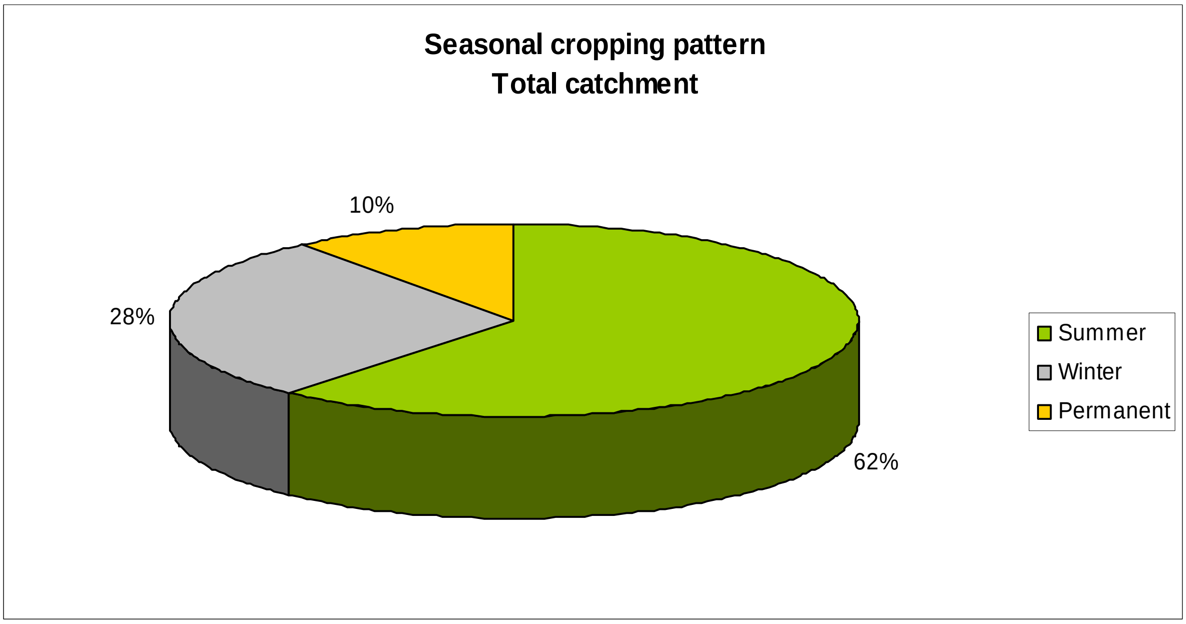
6.4.7 Seasonal cropping pattern

The seasonal cropping patterns, based upon the cultivation practices during the 2003 hydrological year are:

Table 13: Seasonal cropping pattern

	Summer	Winter	Permanent
A42A	59.56%	28.50%	11.95%
A42B	63.28%	30.37%	6.35%
A42C	50.98%	27.57%	21.45%
A42D	55.34%	44.66%	0.00%
A42E	70.66%	25.56%	3.78%
A42F	66.12%	32.35%	1.53%
A42G	58.10%	6.67%	35.24%
A42H	63.85%	31.38%	4.78%
A42J	55.22%	23.38%	21.40%
Total	**61.42%**	**28.15%**	**10.43%**

This is better shown in the following graph:



6.4.8 Maximum possible irrigation development

Based upon the provisions contained in the two Government Water Control Areas, the scheduled water within the Irrigation Board and the unrestricted use of borehole water allowed for under the previous Water Act, the following areas and volumes may legally have been developed in the different catchments:

Table 14: Maximum possible irrigation

Quaternary	Area	Volume
A42A	4 362.10	39 496 736
A42B	3 534.09	31 965 744
A42C	5 370.92	48 529 413
A42D	1 049.05	9 598 808
A42E	6 630.71	59 908 179
A42F	2 926.35	26 275 470
A42G	653.14	4 636 480
A42H	1 004.40	7 030 800
A42J	1 851.56	12 951 437
Total	**27 382.32**	**240 393 065**

The previous Act therefore allowed for the taking of some **240 million cubic metres** per annum from the surface and underground water resources.

6.4.9 Registered irrigation development

The latest registration data shows the following crop areas to be registered:

Table 15: Registered irrigation crop area

Quaternary	Surface (ha)	Scheme (ha)	Borehole (ha)	Total (ha)
A42A	3196.82	0.00	475.50	3672.32
A42B	2748	0.00	629.90	3377.90
A42C	2782.9	0.00	635.30	3418.20
A42D	241.2	0.00	10.00	251.2
A42E	3089.5	0.00	448.50	3538.00
A42F	1052.8	0.00	145.30	1198.10
A42G	1.5	623.14	2.00	626.64
A42H	2.7	1 004.40	17.00	1024.1
A42J	0	1 840.90	178.50	2019.4
Total	**13 115.42**	**3 468.44**	**2 542.00**	**19 125.86**

The registered annual taking of water is:

Table 16: Registered irrigation volume

Quaternary	Surface (m^3)	Scheme (m^3)	Borehole (m^3)	Total (m^3)
A42A	15 580 676	0	1 328 903	16 909 579
A42B	12 732 703	0	2 474 110	15 206 813
A42C	13 069 303	0	3 270 204	16 339 507
A42D	1 396 385	0	111 100	1 507 485
A42E	12 488 679	0	1 505 513	13 994 192
A42F	4 678 021	0	864 597	5 542 618
A42G	5 760	4 361 980	12 480	4 380 220
A42H	5 316	7 030 800	90 702	7 126 818
A42J	0	12 886 300	739 958	13 626 258
Total	**59 956 843**	**24 279 080**	**10 397 567**	**94 633 490**

Some **19 125 ha** of irrigated crop area taking some **94.6 million cubic metres** per annum were registered.

6.4.10 Existing lawful water use

The results of the validation process show the preliminary existing lawful water use from all water resources, including the Irrigation Board scheduling, to be as follows:

Table 17: Existing lawful water use

Quaternary	Area (ha)	Volume (m³/a)
A42A	1 693.02	10 689 428
A42B	1 442.59	8 988 529
A42C	1 693.77	10 429 365
A42D	465.81	1 751 457
A42E	2 592.06	13 708 553
A42F	950.61	5 495 779
A42G	624.64	4 368 670
A42H	1 004.40	7 030 800
A42J	1 851.56	12 951 437
Total	**12 318.47**	**75 414 018**

Here it must be noted that the total scheduled water use in the Irrigation Board is 3 468.44 ha, giving a total annual volume of 24 279 080 m³. The actual irrigation water use within the Irrigation Board amounts to 9 581 400 m³ (1998 hydrological year) or some 6 671 500 m³ (2003 hydrological year).

This difference of between 14 700 000 m³ and 17 600 000 m³ exists only because of the declaration by the Minister of Water Affairs and Forestry of scheduled irrigation board water to be existing lawful water use. This means that the real existing lawful water use for the whole study area ranges between **59,1 million m³** and **56,2 million m³** per annum.

6.4.11 Actual annual water use

A comparison of the actual annual water use for irrigation, as calculated from the irrigation demand model, with the existing lawful water use (ELU) is shown in the following table:

Table 18: Actual annual water use (not restricted)

Quaternary	1985 area	1998 area	2004 area	ELU
A42A	9 030 721	7 761 690	9 710 281	10 689 428
A42B	8 045 542	6 710 520	7 320 780	8 988 529
A42C	9 658 825	6 879 713	9 077 900	10 429 365
A42D	4 378 793	1 293 990	1 461 420	1 751 457
A42E	20 352 072	13 576 328	9 781 260	13 708 553
A42F	5 586 500	5 638 598	4 850 700	5 495 779
Total	**57 052 453**	**41 860 839**	**42 202 341**	**51 063 111**
A42G	740 123	496 083	403 778	4 368 670
A42H	1 854 133	980 346	1 064 658	7 030 800
A42J	9 015 830	9 067 463	5 878 319	12 951 437
Total	**11 610 087**	**10 543 893**	**7 346 754**	**24 350 907**
Grand total	**68 662 540**	**52 404 731**	**49 549 095**	**75 414 018**

Should the drought reduction factor be taken into account, the actual annual water use compared to the ELU is as follows:

Table 19: Actual annual water use (drought restricted)

Quaternary	1985 area	1998 area	2004 area	ELU
A42A	9 030 721	7 651 627	9 370 599	10 689 428
A42B	8 040 201	5 856 098	7 320 780	8 988 529
A42C	9 658 825	5 738 081	9 077 900	10 429 365
A42D	4 378 793	1 099 681	1 461 420	1 751 457
A42E	20 352 072	10 532 198	9 781 260	13 708 553
A42F	5 586 500	4 348 967	4 850 700	5 495 779
Total	**57 047 112**	**35 226 651**	**41 862 660**	**51 063 111**
A42G	678 830	351 275	403 778	4 368 670
A42H	1 738 430	620 086	961 477	7 030 800
A42J	8 702 432	8 767 864	5 878 319	12 951 437
Total	**11 119 692**	**9 739 226**	**7 243 573**	**24 350 907**
Grand total	**68 166 803**	**44 965 877**	**49 106 233**	**75 414 018**

The differences between the Existing Lawful Use and the actual water use can mainly be ascribed to the fact that the ELU is based upon average irrigation requirements, while the actual water use is based upon the actual requirements during a particular year with a particular set of climatic conditions.

6.4.12 Typical fixed area time series

Time series records were developed for all quaternary catchments and sub catchments. A typical graphical representation of such a time series is:

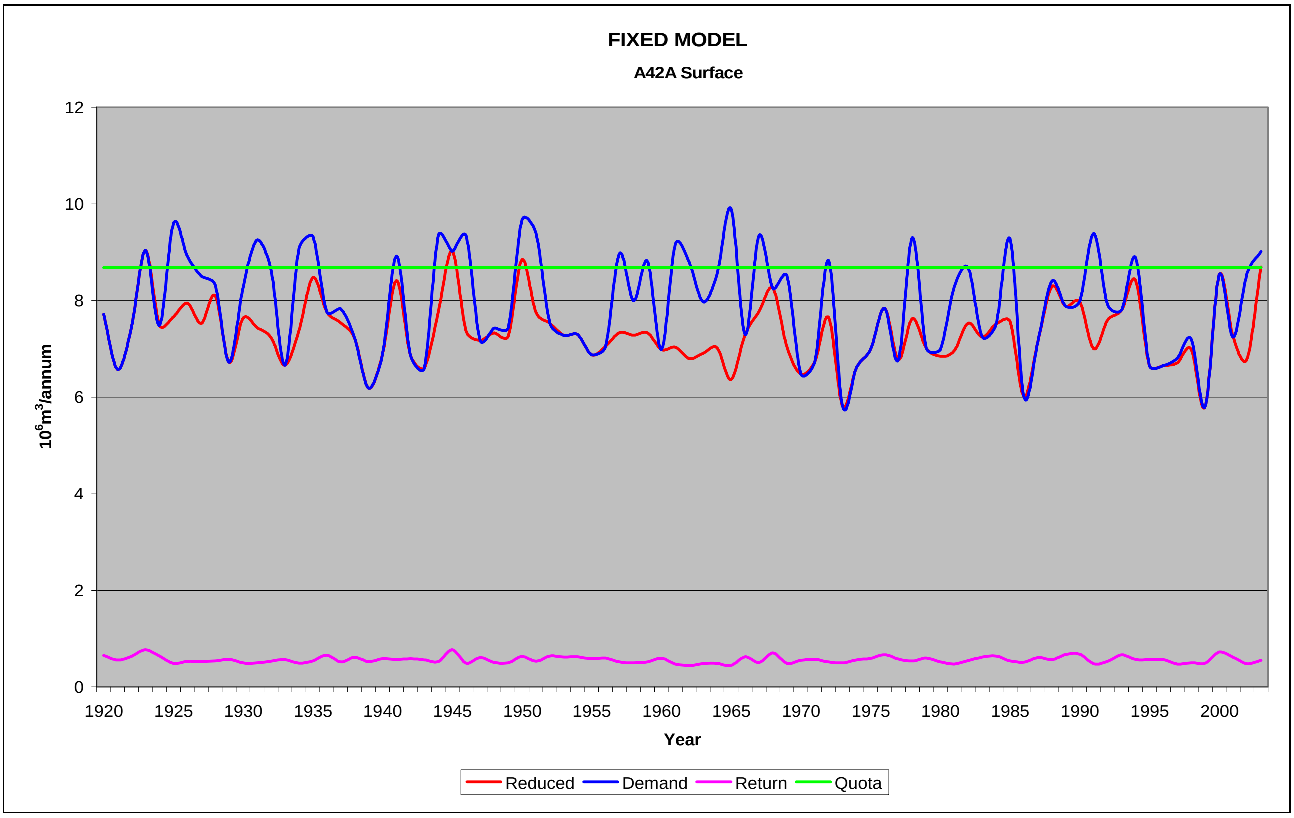


Figure 6: Fixed area time series

6.4.13 Typical growth area time series

Time series records were developed for all quaternary catchments and sub catchments. A typical graphical representation of such a time series is:

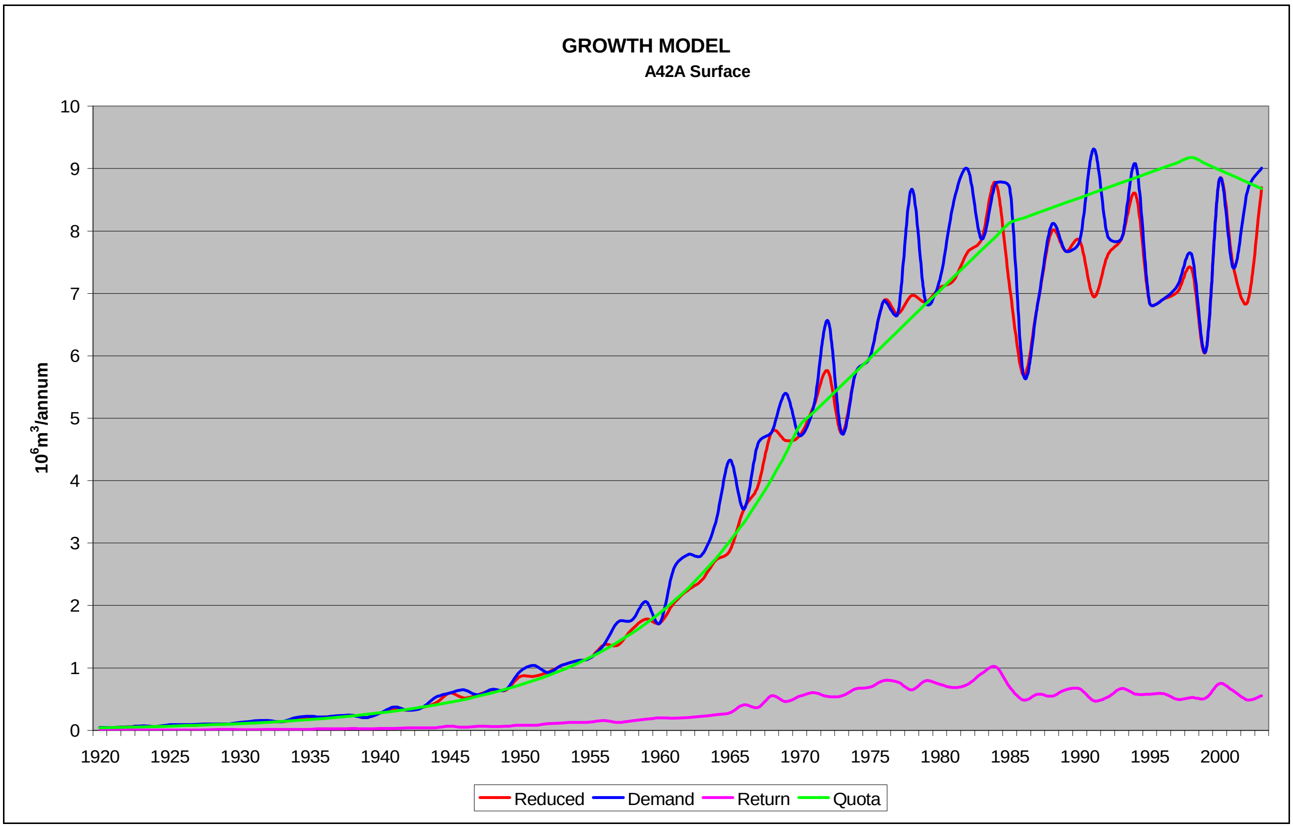


Figure 7: Growth area time series

6.4.14 Model user interface

A typical example of the user interface of the irrigation model is shown in the following figure:

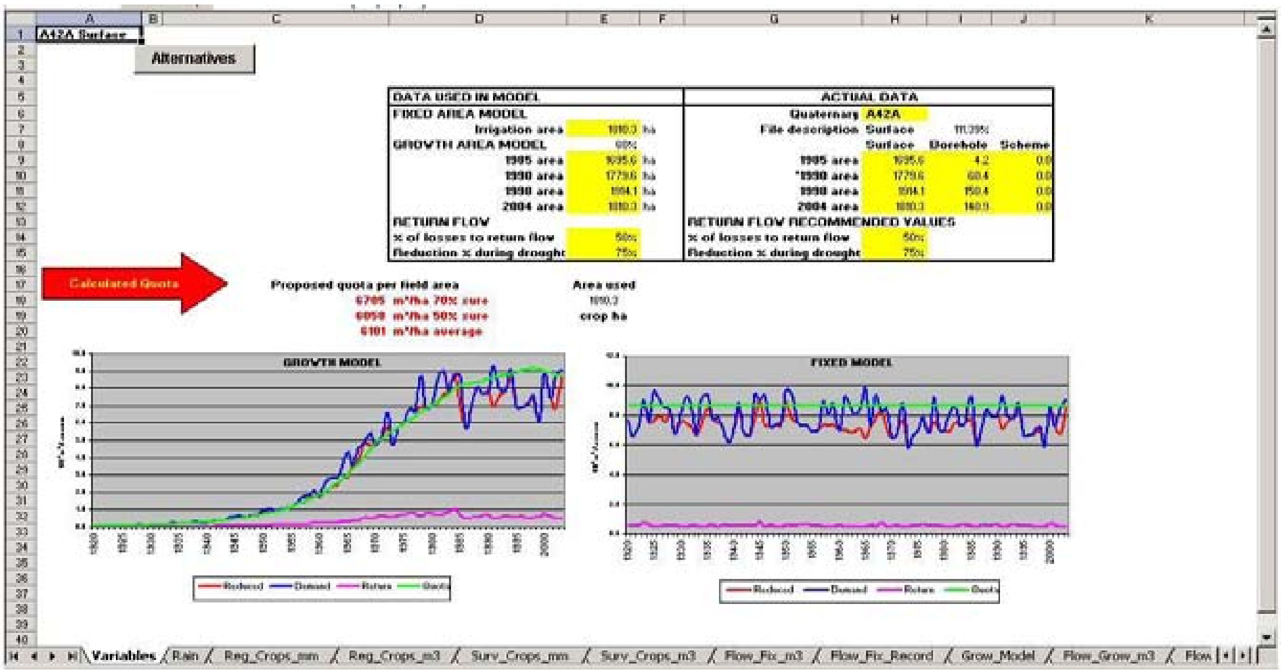


Figure 8: User interface

7 STORING OF WATER

7.1 SUMMARY

7.1.1 History

In January 1989 Schoeman en Van der Merwe reported in detail on irrigation development and farm dams in the catchment of the Mokolo dam. This report, with DWAF reference number P. A400/00/0389 formed part of a series of three reports on the Mokolo River Augmentation Scheme.

During the investigations preceding the report, a number of dams in the catchment were investigated. Some sixty larger reservoirs were surveyed in detail. A further 585 dams were investigated by measuring the surface areas, depths and backwater lengths.

Capacity : Depth relationships and Area : Depth relationships were developed for all of the dams, based on the actual surveyed dam characteristics. The following relationships were found:

Volume: $V_H = C_V \times D_H{}^x$

where: V_H = Volume at particular depth (m³)
C_V = Constant for the particular dam
D_H = Depth (m)
x = Characteristic exponent of the particular dam

Area: $A_H = C_A \times D_H{}^y$

where: A_H = Volume at particular depth (m³)
C_A = Constant for the particular dam
D_H = Depth (m)
y = Characteristic exponent of the particular dam

The following exponents were identified through a process of linear regression for the x-exponent in the capacity : depth relationship:

Table 20: Capacity depth exponent

Type of dam	**x**
Weir	2.000
Balancing dam	1.807
Storage dam	
≤ 100 000 m³	2.393
100 000 < volume ≤ 200 000 m³	2.216
200 000 < volume ≤ 300 000 m³	2.512
> 300 000 m³	2.459

The following exponents were identified through a process of linear regression for the y-exponent in the area : depth relationship:

Table 21: Area depth exponent

Type of dam	**y**
Weir	1.000
Balancing dam	1.141
Storage dam	
≤ 5 ha	2.393
5 ha < area ≤ 10 ha	2.216
10 ha < area ≤ 15 ha	2.512
> 15 ha	2.459

The constants C_V were found by $C_V = \frac{FullSupplyCapacity}{FullSupplyDepth^x}$

The constants CA were found by $C_A = \frac{FullSupplyArea}{FullSupplyDepth^y}$

7.1.2 New model

Based upon the validation process conducted in the Mokolo catchment, a new set of storages was identified. These storages were classified as weirs, storage dams, pans, gravel pits and mine (slimes) dams.

The surface areas and depths of the different dams were determined from previous survey data, registration information and/or measurements from the digital terrain model underlying the GIS that was created for the area.

The constants and exponents found in the previous study were applied to the new set of storages and the results grouped per storage type, catchment and sub catchment.

Spreadsheet based models were then created for the original surveyed dams, the dams in 1998, the dams in 2004 and the **preliminary** validated existing lawful dams.

The spreadsheet models are set up in a way that allows for any subset of a particular dam type to be displayed and analysed. It is therefore possible to directly obtain the characteristics of any group of dams within a catchment or sub catchment. The idea is to be able to define a representative storage mimicking a number of actual storages within a defined subset.

When a particular subset of a particular dam type on a particular date is chosen, the model immediately calculates the constant and exponent of the representative dam. The equation **Area = a*Volume^b** is defined by linear regression of the logarithms of the aggregated volumes and areas. The constant **a** and exponent **b** are displayed immediately for any subset chosen.

The model also generates a table showing the area : capacity values for the representative dam.

7.1.3 Storage development

From the detailed analyses an increase in the total storage since 1985 was detected.

The total storage in **1985** was some **24 960 200 m^3**.

During **1998** this storage increased to **28 308 353 m^3**.

The latest storage identified in **2004** is some **31 134 228 m^3**.

The preliminary **existing lawful** storage is some **27 950 366 m^3**.

While some of the increases in storage were lawful through the issuing of permits under the previous Water Act, or licences under the new Water Act there is currently some 10.2 % or some 3 183 862 m^3 of the current storage development that may be unlawful.

The historical development of storages in the Mokolo catchment is summarised in the following set of tables. The detailed analyses in the models are included in **Annexure I**.

Table 22: Storage data: Survey 1985

		A42A	A42B	A42C	A42D	A42E	A42F	Total	A42G	A42H	A42J	Total	Grand total
Weir	Number	41	5	17	12	36	36	**147**	0	0	0	**0**	**147**
	Volume	543 302	2 990	39 808	37 910	1 309 547	520 176	**2 453 734**	0	0	0	**0**	**2 453 734**
	Area	241 282	4 837	63 495	56 221	967 276	508 587	**1 841 698**	0	0	0	**0**	**1 841 698**
Storage	Number	131	135	140	64	172	53	**695**	57	75	31	**163**	**858**
	Volume	1 093 717	4 951 320	2 374 804	1 419 947	2 574 588	360 490	**12 774 867**	494 652	1 284 601	212 832	**1 992 084**	**14 766 951**
	Area	740 738	3 052 919	1 673 585	753 000	1 579 028	338 873	**8 138 143**	422 915	891 030	379 974	**1 693 919**	**9 832 062**
Pan	Number	0	0	0	0	0	0	**0**	0	9	59	**68**	**68**
	Volume	0	0	0	0	0	0	**0**	0	308 842	384 266	**693 108**	**693 108**
	Area	0	0	0	0	0	0	**0**	0	619 445	768 533	**1 387 978**	**1 387 978**
Gravel pit	Number	5	8	4	1	26	3	**47**	10	8	26	**44**	**91**
	Volume	64 982	113 195	55 059	28 921	626 638	97 130	**985 925**	409 950	207 489	824 187	**1 441 626**	**2 427 551**
	Area	48 449	88 451	39 176	15 718	457 171	61 132	**710 097**	209 072	166 594	521 453	**897 119**	**1 607 216**
Mine	Number	0	0	0	0	1	0	**1**	0	8	26	**34**	**35**
	Volume	0	0	0	0	3 361	0	**3 361**	0	122 837	4 492 658	**4 615 495**	**4 618 856**
	Area	0	0	0	0	1 680	0	**1 680**	0	107 378	2 149 886	**2 257 264**	**2 258 944**
TOTAL	Number	177	148	161	77	235	92	**890**	67	100	142	**309**	**1 199**
	Volume	1 702 001	5 067 505	2 469 671	1 486 779	4 514 134	977 796	**16 217 886**	904 602	1 923 769	5 913 943	**8 742 313**	**24 960 200**
	Area	1 030 469	3 146 207	1 776 256	824 939	3 005 155	908 592	**10 691 618**	631 987	1 784 447	3 819 846	**6 236 280**	**16 927 898**

Table 23: Storage data: 1998

		A42A	A42B	A42C	A42D	A42E	A42F	Total	A42G	A42H	A42J	Total	Grand total
Weir	Number	44	5	17	13	38	39	**156**	0	0	0	**0**	**156**
	Volume	558 020	2 990	39 808	41 374	1 330 287	679 671	**2 652 150**	0	0	0	**0**	**2 652 150**
	Area	253 435	4 837	63 495	57 861	999 725	647 014	**2 026 367**	0	0	0	**0**	**2 026 367**
Storage	Number	162	149	168	72	218	68	**837**	65	83	35	183	**1 020**
	Volume	1 601 396	5 376 129	3 211 476	1 463 446	3 472 812	543 039	**15 668 297**	560 587	1 420 297	229 386	2 210 269	**17 878 566**
	Area	1 138 828	3 101 846	2 011 261	781 027	2 099 199	482 873	**9 615 034**	538 314	984 959	413 455	1 936 728	**11 551 762**
Pan	Number	0	0	0	0	0	0	**0**	0	9	59	**68**	**68**
	Volume	0	0	0	0	0	0	**0**	0	308 842	384 266	**693 108**	**693 108**
	Area	0	0	0	0	0	0	**0**	0	619 445	768 533	**1 387 978**	**1 387 978**
Gravel pit	Number	5	8	4	1	26	3	**47**	10	8	26	**44**	**91**
	Volume	64 982	113 195	55 059	28 921	626 638	97 130	**985 925**	409 950	207 489	826 378	**1 443 817**	**2 429 741**
	Area	48 449	88 451	39 176	15 718	457 171	61 132	**710 097**	209 072	166 594	521 453	**897 119**	**1 607 216**
Mine	Number	0	0	0	0	1	0	**1**	0	8	27	**35**	**36**
	Volume	0	0	0	0	3 361	0	**3 361**	0	122 837	4 528 590	**4 651 427**	**4 654 788**
	Area	0	0	0	0	1 680	0	**1 680**	0	107 378	2 179 829	**2 287 207**	**2 288 887**
TOTAL	Number	**211**	**162**	**189**	**86**	**283**	**110**	**1 041**	**75**	**108**	**147**	**330**	**1 371**
	Volume	**2 224 398**	**5 492 313**	**3 306 344**	**1 533 741**	**5 433 098**	**1 319 839**	**19 309 732**	**970 537**	**2 059 465**	**5 968 619**	**8 998 621**	**28 308 353**
	Area	**1 440 712**	**3 195 134**	**2 113 932**	**854 606**	**3 557 775**	**1 191 019**	**12 353 178**	**747 386**	**1 878 376**	**3 883 270**	**6 509 032**	**18 862 210**

Table 24: Storage data: 2004

		A42A	A42B	A42C	A42D	A42E	A42F	Total	A42G	A42H	A42J	Total	Grand total
Weir	Number	42	6	17	13	38	40	**156**	0	0	0	**0**	**156**
	Volume	555 585	17 480	39 808	41 374	1 330 287	690 675	**2 675 209**	0	0	0	**0**	**2 675 209**
	Area	248 191	23 928	63 495	57 861	999 725	657 119	**2 050 319**	0	0	0	**0**	**2 050 319**
Storage	Number	164	153	170	74	225	75	**861**	69	94	42	**205**	**1 066**
	Volume	1 616 298	5 645 341	3 275 613	3 638 227	3 570 239	622 798	**18 368 518**	562 546	1 462 506	286 542	**2 311 593**	**20 680 111**
	Area	1 145 491	3 231 827	2 058 414	1 118 362	2 143 411	530 844	**10 228 349**	563 262	1 045 310	543 769	**2 152 341**	**12 380 690**
Pan	Number	0	0	0	0	0	0	**0**	0	9	59	**68**	**68**
	Volume	0	0	0	0	0	0	**0**	0	308 842	384 266	**693 108**	**693 108**
	Area	0	0	0	0	0	0	**0**	0	619 445	768 533	**1 387 978**	**1 387 978**
Gravel pit	Number	5	8	4	1	26	3	**47**	10	8	26	**44**	**91**
	Volume	64 982	113 195	55 059	28 921	626 638	97 130	**985 925**	409 950	207 489	824 187	**1 441 626**	**2 427 551**
	Area	48 449	88 451	39 176	15 718	457 171	61 132	**710 097**	209 072	166 594	519 627	**895 293**	**1 605 390**
Mine	Number	0	0	0	0	1	0	**1**	0	9	27	**36**	**37**
	Volume	0	0	0	0	3 361	0	**3 361**	0	126 298	4 528 590	**4 654 888**	**4 658 249**
	Area	0	0	0	0	1 680	0	**1 680**	0	110 262	2 179 829	**2 290 091**	**2 291 771**
TOTAL	Number	**211**	**167**	**191**	**88**	**290**	**118**	**1 065**	**79**	**120**	**154**	**353**	**1 418**
	Volume	**2 236 865**	**5 776 016**	**3 370 481**	**3 708 522**	**5 530 525**	**1 410 603**	**22 033 012**	**972 495**	**2 105 135**	**6 023 585**	**9 101 215**	**31 134 228**
	Area	**1 442 131**	**3 344 206**	**2 161 085**	**1 191 941**	**3 601 987**	**1 249 095**	**12 990 445**	**772 334**	**1 941 611**	**4 011 758**	**6 725 703**	**19 716 148**

Table 25: Storage data: Existing Lawful

		A42A	A42B	A42C	A42D	A42E	A42F	Total	A42G	A42H	A42J	Total	Grand total
Weir	**Number**	40	5	17	12	36	38	**148**	0	0	0	**0**	**148**
	Volume	541 435	2 990	39 808	37 910	1 309 547	652 524	**2 584 214**	0	0	0	**0**	**2 584 214**
	Area	238 318	4 837	63 495	56 221	967 276	600 405	**1 930 552**	0	0	0	**0**	**1 930 552**
Storage	**Number**	134	138	138	65	180	57	**712**	55	74	31	160	**872**
	Volume	1 102 195	5 138 690	2 744 975	3 594 347	2 685 735	402 451	**15 668 393**	431 721	1 272 107	212 832	1 916 660	**17 585 053**
	Area	789 913	2 972 971	1 696 340	1 089 178	1 603 450	360 513	**8 512 365**	419 090	880 514	379 974	1 679 578	**10 191 943**
Pan	**Number**	0	0	0	0	0	0	**0**	0	9	59	**68**	**68**
	Volume	0	0	0	0	0	0	**0**	0	308 842	384 266	**693 108**	**693 108**
	Area	0	0	0	0	0	0	**0**	0	619 445	768 533	**1 387 978**	**1 387 978**
Gravel pit	**Number**	5	8	4	1	26	3	**47**	10	8	26	**44**	**91**
	Volume	64 982	113 195	55 059	28 921	626 638	97 130	**985 925**	409 950	207 489	826 378	**1 443 817**	**2 429 742**
	Area	48 449	88 451	39 176	15 718	457 171	61 132	**710 097**	209 072	166 594	521 453	**897 119**	**1 607 216**
Mine	**Number**	0	0	0	0	1	0	**1**	0	9	27	**36**	**37**
	Volume	0	0	0	0	3 361	0	**3 361**	0	126 298	4 528 590	**4 654 888**	**4 658 249**
	Area	0	0	0	0	1 680	0	**1 680**	0	110 262	2 179 829	**2 290 091**	**2 291 771**
TOTAL	**Number**	**179**	**151**	**159**	**78**	**243**	**98**	**908**	**65**	**100**	**143**	**308**	**1 216**
	Volume	**1 708 612**	**5 254 875**	**2 839 842**	**3 661 178**	**4 625 281**	**1 152105**	**19 241 892**	**841 671**	**1 914 736**	**5 952 065**	**8 708 472**	**27 950 366**
	Area	**1 076 680**	**3 066 259**	**1 799 011**	**1 161 117**	**3 029 577**	**1 022 050**	**11 154 692**	**628 162**	**1 776 815**	**3 849 789**	**6 254 766**	**17 409 460**

The characteristics of the existing lawful storages were further analysed to obtain frequency distributions for different characteristics. The results of this analysis are shown in the following tables:

Table 26: Capacity analysis

Size (m³)	Weir	Storage	Pan	Gravel pit	Mine	Total
5 000	104	563	40	13	9	**729**
10 000	11	110	20	16	6	**163**
50 000	21	135	5	48	11	**220**
100 000	7	28	1	10	2	**48**
150 000	2	15	1	1	0	**19**
250 000	1	9	1	3	4	**18**
500 000	1	7	0	0	2	**10**
1 000 000	1	4	0	0	2	**7**
1 500 000	0	0	0	0	1	**1**
2 000 000	0	0	0	0	0	**0**
> 2 000 000	0	1	0	0	0	**1**
Total	**148**	**872**	**68**	**91**	**37**	**1216**

Table 27: Surface area analysis

Area (m²)	Weir	Storage	Pan	Gravel pit	Mine	Total
5 000	97	503	16	10	7	**633**
10 000	13	172	24	30	8	**247**
15 000	9	54	18	19	3	**103**
20 000	7	39	2	12	2	**62**
25 000	5	25	3	3	2	**38**
30 000	1	16	0	3	1	**21**
35 000	1	10	1	3	1	**16**
40 000	3	8	0	2	2	**15**
50 000	1	11	1	1	2	**16**
75 000	6	14	0	6	0	**26**
100 000	2	4	0	2	1	**9**
150 000	1	7	0	0	4	**12**
200 000	1	3	1	0	1	**6**
250 000	0	2	1	0	1	**4**
300 000	1	1	0	0	0	**2**
400 000	0	3	1	0	1	**5**
500 000	0	0	0	0	1	**1**
> 500 000	0	0	0	0	0	**0**
Total	**148**	**872**	**68**	**91**	**37**	**1216**

Table 28: Depth analysis

Depth (m)	Weir	Storage	Pan	Gravel pit	Mine	Total
1.0	30	159	68	3	1	**261**
1.5	38	183	0	6	3	**230**
2.0	31	152	0	9	1	**193**
2.5	14	79	0	3	0	**96**
3.0	10	93	0	28	22	**153**
4.0	9	81	0	34	6	**130**
5.0	10	60	0	4	1	**75**
10.0	5	61	0	4	3	**73**
15.0	1	3	0	0	0	**4**
20.0	0	1	0	0	0	**1**
> 20.0	0	0	0	0	0	**0**
Total	**148**	**872**	**68**	**91**	**37**	**1216**

The effective depth is defined by dividing the full supply capacity by the full supply area. An analysis of the effective depths shows the following:

Table 29: Effective depth analysis

Effective Depth (m)	Weir	Storage	Pan	Gravel pit	Mine	Total
0.2	24	23	0	0	0	**47**
0.4	33	150	0	2	0	**185**
0.6	26	173	68	6	5	**278**
0.8	19	105	0	2	0	**126**
1.0	18	120	0	11	1	**150**
1.5	15	140	0	46	21	**222**
2.0	6	85	0	20	6	**117**
2.5	3	41	0	4	2	**50**
3.0	2	14	0	0	0	**16**
3.5	1	4	0	0	0	**5**
4.0	1	5	0	0	1	**7**
4.5	0	4	0	0	1	**5**
5.0	0	1	0	0	0	**1**
> 5.0	0	7	0	0	0	**7**
Total	**148**	**872**	**68**	**91**	**37**	**1216**

8 LAND USE

8.1 SUMMARY

As mentioned previously in this report, the cultivation of fields has the effect that the hydrological response may be affected. All cultivated fields and irrigated fields were digitized and spatially linked in the GIS. Land use was classified within quaternary catchments and also sub classified within the sub catchments.

The results of the land use in 1998 and in 2004 are shown in the following tables:

Table 30: Land use: 1998

Quaternary catchment	Area (ha)	Cultivated (ha)	Irrigated (ha)	Total fields (ha)	%Cultivated	%Irrigated	%Total fields
A42A	57 316	10 864	1 456	12 320	18.96%	2.54%	21.50%
A42B	52 129	13 891	1 447	15 338	26.65%	2.78%	29.42%
A42C	69 803	9 857	1 464	11 321	14.12%	2.10%	16.22%
A42D	49 629	3 728	526	4 254	7.51%	1.06%	8.57%
A42E	100 676	8 189	3 815	12 005	8.13%	3.79%	11.92%
A42F	102 100	2 870	1 449	4 319	2.81%	1.42%	4.23%
A42G	120 540	3 132	56	3 189	2.60%	0.05%	2.65%
A42H	105 598	3 989	189	4 178	3.78%	0.18%	3.96%
A42J	180 920	4 975	488	5 464	2.75%	0.27%	3.02%
Total	**838 711**	**61 497**	**10 891**	**72 388**	**7.33%**	**1.30%**	**8.63%**

Table 31: Land use: 2004

Quaternary catchment	Area (ha)	Cultivated (ha)	Irrigated (ha)	Total fields (ha)	%Cultivated	%Irrigated	%Total fields
A42A	57 316	7 982	1 795	9 777	13.93%	3.13%	17.06%
A42B	52 129	8 073	1 710	9 782	15.49%	3.28%	18.77%
A42C	69 803	9 577	1 824	11 401	13.72%	2.61%	16.33%
A42D	49 629	1 280	613	1 893	2.58%	1.24%	3.81%
A42E	100 676	4 715	3 946	8 661	4.68%	3.92%	8.60%
A42F	102 100	496	1 448	1 945	0.49%	1.42%	1.90%
A42G	120 540	3 563	35	3 598	2.96%	0.03%	2.98%
A42H	105 598	3 787	266	4 053	3.59%	0.25%	3.84%
A42J	180 920	4 633	783	5 416	2.56%	0.43%	2.99%
Total	**838 711**	**44 106**	**12 420**	**56 526**	**5.26%**	**1.48%**	**6.74%**

9 VERIFICATION OF WATER USES

The verification of water use can be described as the process of exchange of information between DWAF and the water user in order to make a final determination of the existing lawful water use on a property.

During the validation of water use and the determination of the lawful use, very little formal communication between the water user and DWAF took place. The classification of the registered use and the identification of unlawful water use were “internal” investigations and the answers obtained are not final.

The main aim of the verification process is to inform a water user of the outcomes of the validation process and to offer the water user (if he/she disagrees) the opportunity to make representations regarding any determinations made during the validation process. The verification of water use is a formal process described under Section 35 of the National Water Act and the following tasks have been identified:

The section 35 process can only be initiated by DWAF, and all the correspondence is between DWAF and the water user. The whole process can be a lengthy exercise and is graphically shown in Figure 9.

All the validation results have been captured on a supporting database and the validation team will assist the Region Office with the drafting and printing of the first letter of the section 35 process (Letter A).

Letter A has three basic functions, namely:

- Informing the water user of the results of the validation process
- Requesting the user to apply for the verification of water use before a set date.
- Requesting the water user to supply proof and/or additional information should he/she disagree with the validation results.

The main challenge of the section 35 process will be the evaluation of representations made by the water users if they disagree with the results of the validation process.

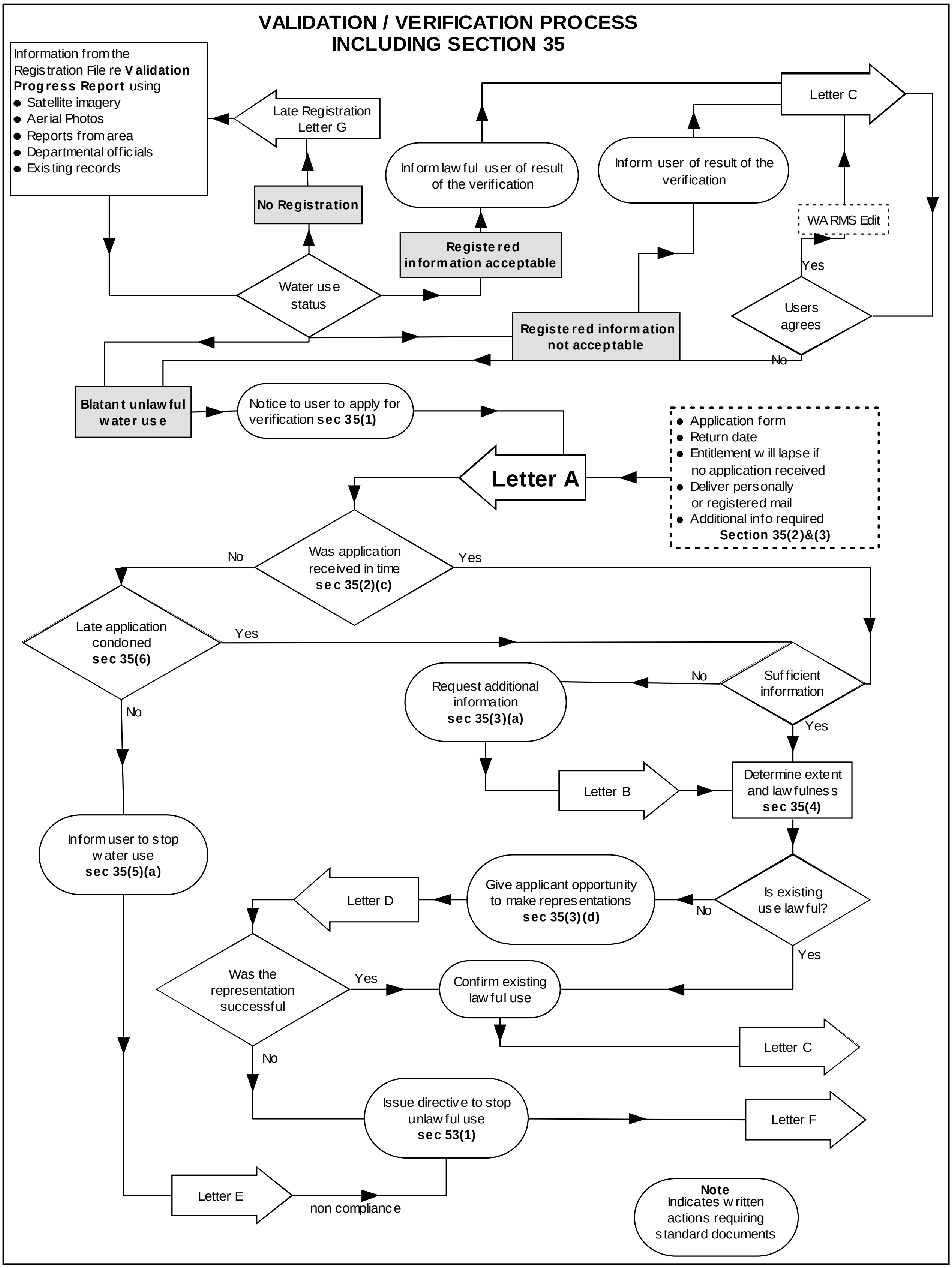


Figure 9: Section 35 process

10 SUMMARY

From the results obtained from the study it is evident that a substantial change in farming practices occurred within the catchment of the Mokolo River whereby the actual extent under irrigation from surface water resources decreased by some 3 600 ha or 35 million m^3/a between the mid 1980's and 1998/99.

A summary of the validated water uses in terms of irrigation volumes per annum is presented in Table 32.

Table 32: Summary: Annual irrigation volumes (m^3)

Water resource	Lawful use (ha)	Field surveys 1985 (ha)	Existing use 1998/99 (ha)	Current use 2004 (ha)	Existing lawful use (ha)	Registered use (ha)
Surface water	211 134 146	87 074 400	52 221 026	47 909 118	46 155 099	59 956 843
Groundwater	4 979 839	1 744 470	4 979 839	5 676 070	4 979 839	10 397 567
Scheme	24 279 080	11 406 275	10 961 911	7 875 730	24 279 080	24 279 080
Total	**240 393 065**	**100 225 145**	**68 162 776**	**61 460 918**	**75 414 018**	**94 633 490**

From the table above it is evident that during the 1998/99 period, water users were abstracting some 6 million m^3/a more from surface water resources than they were lawfully entitled to. The current annual abstraction from surface water resources is some 1.7 million m^3 more that the existing lawful entitlement.

In terms of ground water resources the current annual abstraction of 5 676 070 m^3/a is some 700 000 m^3 more that the existing lawful entitlement of 4 979 839 m^3/a.

A summary of validation results in terms of irrigation volumes per annum is presented in Table 33.

Table 33: Summary: Classified water use volumes (m^3)

Water resource	Correctly registered	Over registered	Under registered	Existing lawful use	Possible unlawful use in 1998/99	Possible unlawful use in 2004
Surface water	31 301 502	28 655 341	14 853 597	46 155 099	6 241 731	7 432 047
Ground water	3 786 474	7 327 580	1 909 852	4 979 839	0	1 166 734
Scheme	24 279 080	0	0	24 279 080	0	0
Total	**59 367 056**	**35 982 921**	**16 763 449**	**75 414 018**	**6 241 731**	**8 598 781**

From the table above it is evident that the nett result of the validation process is an over registration of some 19.2 million m^3/a while possible unlawful use during the qualifying period amounted to some 6.2 million m^3/a. The possible unlawful use in 2004 increased to some 8.6 million m^3/a.

A summary of the validated storage is presented in Table 34.

Table 34: Summary: Storing of water (m^3)

Totals	Field surveys 1985	Existing use 1998/99	Current use 2004	Possible existing lawful
Number	1 199	1 371	1 418	1 216
Volume (m^3)	24 960 200	28 308 353	31 134 228	27 950 366
Area (m^2)	16 927 898	18 862 210	19 716 148	17 409 460

From the detailed analyses an increase in the total storage since 1985 was detected. The total storage in 1985 was some 24 960 200 m^3. During 1998 this storage increased to 28 308 353 m^3. The latest storage identified in 2004 is some 31 134 288 m^3. The preliminary existing lawful storage is some 27 950 366 m^3.

While some of the increases in storage were lawful there is currently some 10.2 % or some 3 183 862 m^3 of the current storage development that may be unlawful.

11 RECOMMENDATIONS

Throughout the duration of the project the team received excellent cooperation and feedback from water users within the study area. This can mainly be attributed to the fact that the irrigation sector is well organised through river committees and irrigation forums. These users are anxious to have their water uses verified for future planning purposes and for the management of water resources. Various users are also seeking additional water but cannot enter into any temporary or permanent transactions/agreements unless water uses have been verified.

We therefore propose to initiate the section 35 process as soon as practically possible. Apart from the reasons provided above, the verification of water use is critical for the licensing and management/control of water resources since lack thereof may lead to the establishment of claims to water due to over allocation, an unfair or disproportionate use of water from a resource. This can lead to the unacceptable situation that such use goes unnoticed or is perpetuated in future. Any unlawful water use must therefore be curtailed as soon as possible especially with the high turnover in ownership as it places new owners in an untenable situation.

The verification process requires that water users provide additional information if he/she disagrees with the validation results and to provide proof that water use did take place during the qualifying period. Current legislation requires that records need to be stored for a period of five years. The verification process will require that water users provide proof of something that already happened six to eight years ago. Any delay in the verification process will place greater burden not only on water users, but also the Department.

The total scheduled water use in the Mokolo River Irrigation Board is 3 468.44 ha, giving a total annual volume of 24 279 080 m³. In circular 18 of 2001 it is stated that

"All lawful scheduling in terms of section 63 and 88 of the WA for which all due water use rates and charges were paid on 30 September 1998, should be treated as existing lawful water uses in terms of section 33 of the NWA. ……………..These unutilised rights can be treated as existing lawful use until compulsory licensing is required."

The actual irrigation water use within the Irrigation Board amounts to 9 581 400 m³ for the1998 hydrological year or some 6 671 500 m³ for the 2003 hydrological year.

This difference (over-allocation) of between 14 700 000 m³ and 17 600 000 m³ exists only because of the declaration by the Minister of Water Affairs and Forestry of scheduled irrigation board water to be existing lawful water use.

In order to address the current over-allocation of water downstream of the Mokolo Dam it is proposed that compulsory licensing be implemented as soon as possible for this area since it is the only legal mechanism available to rectify the over-allocation problem.